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RELATIONSHIP OF GROWTH CHARACTERISTICS TO SEX AND AGE FOR BLACK BEARS FROM THE ADIRONDACK REGION OF NEW YORK[1]

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ABSTRACT

Data on body measurements, weight, skull measurements, closure of the long bones and closure of skull sutures were related to sex and age for 153 black bears from the Adirondack region of New York. Except for three cubs, age was determined by the tooth-sectioning technique. Growth was found to be curvilinear and, thus, data on body size, weight and skull development cannot be used for determining age. Neither can long-bone closure or skull-suture closure.

By 2½ years, female black bears attain adult size for all standard body measurements. They also become sexually mature by that age. Skull length reaches adult size at 3½ years, and skull width at approximately 4½ years. Long-bone closure begins by 2½ years and is not completed until 8½ years, so the capacity for skeletal growth is present until 8½ years. Data for male bears were scanty, and the age at which they attain adult size was not determined.

Sexual dimorphism is exhibited in black bears as a marked difference in size between males and females. By 1½ years, males are significantly larger in all standard skull measurements except postorbital breadth and least interorbital constriction. The average 2½-year-old male is approximately the same size as the average 8½-year-old female. Sexual dimorphism allows separation of male and female skulls by the length of mandible, palatal length and condylobasilar length.

In 1956, the New York State Conservation Department undertook a program of live trapping and tagging black bears (*Ursus americanus*) as a contract project with Cornell University. The project was under the supervision of C. W. Severinghaus, and field work was directed by Hugh

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C. Black until the fall of 1958 when direction was assumed by the big game project at the Wildlife Research Laboratory at Delmar. From 1956 to 1966, a total of 403 wild bears were trapped, of which 65 were necropsied and 338 were ear tagged and released. A $25 cash reward stimulated hunters to return 62 skulls from ear-tagged animals. Also, 36 untagged specimens were obtained from road kills, sacrificed nuisance bears, and hunters.

The purpose of the present paper is to summarize data on various growth characteristics for this sample of black bears and to evaluate these data in relation to sex and age. This information is considered unique in two respects. First, it constitutes one of the largest collections of data on growth of the black bear. Second, it represents the first attempt to relate growth characteristics to age as determined by the tooth-sectioning technique (Sauer et al., 1966), the most reliable technique for aging black bears developed thus far.

The paper is limited to bears from the Adirondack region. The bear range in this region, 12,311 square miles (Sauer and McCaffrey, 1965), is the largest of the three bear ranges in New York. The majority of the tagging and releasing was accomplished there, and the largest number of nuisance bears and the greatest harvests by hunting have been made there. Only scant information is available from the Catskill and Allegany ranges.

Data analyzed include body measurements, weight, skull measurements, schedule of long-bone closure and schedule of skull-suture closure. Similar data have been used as aging criteria for many mammals. Although the possibility of developing additional techniques for aging black bears from these data is considered, an analysis of gross measurements is useful in itself.

Relatively little is known about black bears in comparison with other game species. Seton (1929) gave the most definitive natural history of the species. A formal definition of size and growth is obviously dependent on an accurate method of determining age. Criteria used in previous attempts to age black bears have included a schedule of skull-suture closure (Stickley, 1957), a tooth-wear technique (Hewitt and Black, 1959) and canine root annulations, skull development and suture closure (Rausch, 1961). None of these methods proved reliable for assigning ages to black bears in New York. Moreover, only Rausch correlated age with growth in body size, but his aging technique, although suitable for Alaskan black bears (from which his data were derived), is not applicable to bears in New York because of a wide difference in the time at which closure of the canine root occurs.

Techniques for assigning ages to other species of bears were not found applicable to the black bear. Manning (1964) developed a series of age groups for the polar bear (*Ursus maritimus*) based on condylobasilar

length, interorbital breadth and coronoid height without known-age skulls as a basis for his technique. Mundy and Fuller (1964) found layering in the cementum of M_3 of the grizzly bear (*Ursus arctos*) and assumed each layer represented a year of growth. They also found a correlation between zygomatic breadth and the number of layers in the cementum, and from this relationship they developed a regression formula for determining age from zygomatic breadth.

Limited data are available on reproduction. Erickson et al. (1964), in a histological study of seasonal changes in the male and female reproductive organs for black bears in Michigan, concluded that estrus in the female is continuous throughout each season, that ovulation is induced by copulation and that breeding in Michigan occurs between mid-June and mid-July. They recorded a mean ovulation rate of 2.4 ova per breeding. They also suggested that the onset of puberty for both sexes comes at 3½ years of age, although they felt that their estimates of age were much more accurate for males than for females. Wimsatt (1963) made a histological study of reproductive organs from the female black bears used in the present study, but he summarized the data on the basis of age assignments made by the tooth-wear method of Hewitt and Black (1959).

MATERIALS AND METHODS

Data for 163 wild black bears were studied, including the 23 known-age specimens which had been used in developing the tooth-sectioning technique and the three cubs whose age was obvious from their size and the presence of milk teeth. Except for 36, all had been trapped and either sacrificed immediately[2] or tagged, released and subsequently taken by hunters.[3] Body measurements were taken at the time of autopsy or, in the case of bears that were trapped and released, when the animal was trapped. Skull measurements were made only after death. The manner in which the data were recorded is described separately for the growth characteristics considered.

AGE DETERMINATION

Once cementum has been formed, it is rarely resorbed (Manley et al., 1955), and any species having a periodic disruption of cementum deposition carries a permanent record of age in its teeth. The black bear is such a species, and the tooth-sectioning technique (Sauer et al., 1966) is the most reliable method for determining the age of these bears that has been developed thus far. In the cementum of the canine, a growth layer is present for each year of the bear's life except the cub year.

[2] A number of females were sacrificed immediately after being trapped in order to obtain their reproductive tracts for needed data on reproduction.

[3] The three cubs that had been trapped and released were taken legally since hunting such bears was permitted in the Adirondack region.

For the 137 specimens not of known age, 127 could be aged by this method. Age was determined from sections of the lower right canine tooth. Sections about 5 millimeters thick were cut from the canine root and decalcified in 20 per cent formic acid. Sections 25 microns thick were then cut with a freezing microtome, and all were stained with hematoxylin and eosin. Although the teeth had been fixed when the skulls were boiled for cleaning, storage in the skulls, for as long as 9 years in some cases, had deteriorated the staining properties of many teeth, and ages could not be assigned to 10 specimens.

Ages for these bears were assigned independently by three different observers, including the author. Yearlings can be aged virtually without error by tooth development as well as by cementum layering. For 114 bears 2½ years old or older, individual age assignments were in agreement for 45 specimens (39 per cent), one year apart for 35 specimens (31 per cent), and two or more years apart for 34 specimens (30 per cent). Single ages for the latter two groups were assigned in a joint conference.

STANDARD BODY MEASUREMENTS

The following standard body measurements, as defined by Hewitt and Black (1959), were used.

EAR LENGTH	Inside ear, from base of deepest notch to tip of ear.
FORE FOOT WIDTH	Bottom of foot, across maximum width of rear sole pad.
HEAD LENGTH	From tip of snout to posterior end of sagittal crest.
HIND FOOT WIDTH	Bottom of foot, across maximum width of rear sole pad.
NECK CIRCUMFERENCE	Taken with steel tape drawn firmly about neck.
SHOULDER HEIGHT	From cranial angle of scapula to bottom of sole pad at heel of extended forelimb.
TAIL LENGTH	Tail reflected and measured from basal vertebra to tip.
TOTAL LENGTH	From tip of snout to tip of tail.
UPPER CANINE LENGTH	On buccal side, from tip of canine to gum line.
UPPER CANINE WIDTH	On buccal side, at gum line.

All measurements were taken after the bear had been anesthetized or killed. Details of trapping and anesthetizing were given by Black et al. (1959). External measurements were taken with a metal rule or steel tape. Dimensions of canines were measured with steel calipers. Over the course of the study, measurements were taken by several workers.

When age assignments were made for animals that had previously been tagged and released, the age at date of kill was back-calculated to the date of original tagging, and only the first set of measurements was used regardless of how many times an animal had been retrapped. Since

aging accuracy is ±1 year for younger bears and ±2 years for older ones, this single use of each individual prevented compounding any age error.

WEIGHT

Weight was taken to the nearest pound with a Chatillon balance or spring balance after the animal had been anesthetized or killed. In addition, dressed weight was obtained for 46 necropsied animals. A live weight-dressed weight regression line was determined for 31 of these bears.

SKULL MEASUREMENTS

Skulls from 115 wild bears could be measured. The following measurements, as defined by Cockrum (1962) except for the Boone and Crockett Club length, but with some modifications for bear skulls, were used.

BASAL LENGTH The distance, in the midline of the skull, from a line connecting the anteriormost parts of the premaxillary bones to the anteriormost inferior border of the foramen magnum.

BOONE AND CROCKETT CLUB LENGTH The distance, in the midline of the skull, from the posteriormost part of the sagittal crest to the anteriormost part of the incisors.

CONDYLE-PREMAXILLAE LENGTH The distance from the posterior margin of a condyle to the most anterior part of the premaxilla on the same side of the skull as the condyle. The point on the premaxilla is not in the median line of the skull.

CONDYLOBASILAR LENGTH The distance, in the midline of the skull, from a line connecting the posteriormost margins of the alveoli of the upper incisors to a line connecting the posteriormost margins of the condyles.

CRANIAL BREADTH The greatest distance across the braincase immediately posterior to the zygomatic arches (in bears, the greatest distance across the parietals).

DEPTH OF CRANIUM Vertical distance from a line connecting the tips of the upper incisors (or canines, whichever is longer) with the most ventral portion of the cranium. Mechanically, this measurement is taken by placing the cranium on a piece of material of known thickness, then measuring the distance from the lower surface of the material to the highest point of the skull and finally subtracting the thickness of the material.

GREATEST LENGTH OF SKULL The over-all length from the anterior tip of the nasals to the structure constituting the most posterior part of the skull (in bears, the sagittal crest).

GREATEST WIDTH ACROSS UPPER MOLARS The greatest distance from the buccal side of the upper left molars to the buccal side of the upper right molars.

LEAST INTERORBITAL CONSTRICTION The least distance across the top of the skull between the orbits.

LENGTH OF MANDIBLE Greatest length of one ramus of the lower jaw, usually not including any part of a tooth that extends forward from the anterior end of the bone.

LENGTH OF MANDIBULAR TOOTH ROW Distance from the anterior aveolus of the canine to the posterior alveolus of the posterior molar.

LENGTH OF MAXILLARY MOLAR SERIES Alveolar distance (unless otherwise specified) from the anterior border of the anterior molar to the posterior border of the posterior molar.

LENGTH OF MAXILLARY TOOTH ROW Distance from the anterior alveolus of the canine to the posterior alveolus of the posterior molar.

MASTOID BREATH The greatest width of the skull across the mastoid bones or processes.

NASALS The usual "length of nasals" is the distance from a line connecting the anteriormost parts to a line connecting the posteriormost extensions of the nasal bones. The "greatest width of the nasals" is usually the distance from the most lateral point of one nasal to the corresponding point on the other.

PALATAL LENGTH The distance, in the midventral line of the skull, from the anteriormost point on the posterior border of the palate (palatine bones) to a line connecting the anteriormost parts of the premaxillary bones (in bears from the posteriormost point on the posterior border of the palate).

POSTORBITAL BREADTH The least distance across the skull posterior to the postorbital processes of the frontal bone.

ZYGOMATIC BREADTH The greatest distance across the zygomatic arches of the cranium perpendicular to the long axis of the skull or the greatest distance between the outer sides of the zygomata.

Each skull was cleaned by boiling, and the author made all skull measurements to the nearest millimeter with steel calipers. Many skulls returned by hunters had been damaged by shot, and not all the desired measurements could be taken.

CLOSURE OF LONG BONES

The long bones and pelvic girdles were collected from 48 necropsied wild bears, and the long bones and phalanges were collected from seven others. A visual scale of 0, 1 and 2 was used to designate whether the epiphyses were open, closing or closed (Figure 1). Open designates

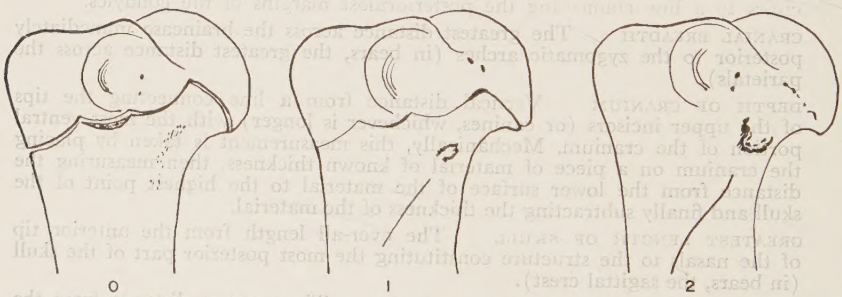

Figure 1. Three stages of closure of the proximal humeral epiphysis: (0) diaphysis and epiphysis separated by a cartilage plate; (1) closure begun; and (2) closure complete.

the condition in the live animal when the diaphysis and epiphysis are completely separated by a cartilage plate. The cartilage plate can be seen when the bones have been boiled; however, it disintegrates rapidly and often the epiphysis separates from the shaft leaving a smooth surface on the end of the shaft. The intermediate or closing stage is the

hardest to determine and presents a major source of error. It includes stages from initial ossification to complete closure. If the epiphysis is broken off at this stage, the bony surfaces of the trabeculae are obvious. The closed stage represents complete union of diaphysis and epiphysis.

CLOSURE OF SKULL SUTURES

Closure of skull sutures was noted on 104 skulls. No scale was devised. The fraction of a suture visibly closed on the outside of the skull was recorded. However, no attempt was made to determine closure on the inside of the skull. Suture closure was considered complete when the bones joined by the suture were completely fused and the suture was no longer visible on the outside of the skull.

REPRODUCTION

Data concerning reproduction were recorded for 47 necropsied females. These data were published by Wimsatt (1963) who used ages based on tooth wear as described by Hewitt and Black (1959). A reevaluation of these data correlated with ages determined by the tooth-sectioning technique is presented.

RESULTS AND DISCUSSION

The data recorded are discussed with respect to the growth characteristics considered in relation to age.

AGE DISTRIBUTION

For the 153 bears for which age could be determined, ages ranged from ½ to 32½ years (Table 1). Their age distribution is not indicative of that in the wild population because collection of specimens was not random. There may have been a difference of as much as 6 months between animals included within the same age group, since specimens were obtained as early as May and as late as December.[4] However, annual age groups are discrete, because denning precludes year-around collection. Only age groups containing five or more specimens were analysed statistically. The small yearly samples limit the scope of this paper, but it is hoped that future collections will make more complete coverage possible.

STANDARD BODY MEASUREMENTS

Standard body measurements were analysed in the following age groups: ½, 1½, 2½, 4½, 5½, 6½, 8½ and 10½+ years for females; and 1½, 2½, 3½, 5½ and 10½+ years for males. Mean measurements

[4] For convenience, all specimens were consider to be one-half year older than their birth-date ages.

TABLE 1. AGE DISTRIBUTION OF BLACK BEAR SPECIMENS USED IN STUDY OF GROWTH CHARACTERISTICS

Age (years)*	Number	
	Male	Female
½	1	2
1½	11	7
2½	10	8
3½	24	6
4½	5	10
5½	7	8
6½	2	5
7½	2	3
8½	2	6
9½	2	3
10½	7	1
11½	..	2
12½	1	1
13½	3	3
14½	1	..
15½	1	1
16½	..	2
17½	..	..
18½	1	1
19½	..	..
20½	..	1
21½	..	..
22½	..	..
23½	..	..
24½	..	..
25½	1	..
26½	..	..
27½	..	..
28½	..	..
29½	..	..
20½–30½	1	..
30½	..	..
31½	..	..
32½	1	..
Undetermined	3	7
Total	86	77

* At time of death, as determined by tooth-sectioning method except for cubs.

are shown in Tables 2 and 3 for females and males, respectively. Growth rate and amount of growth are not the same for all these measurements. Growth curves for total length are shown in Figure 2.

Comparisons between means for males and females were made by computing the standard error of the mean. For each sex, comparisons between yearly means for each measurement were made by an analysis of variance. *F*-values obtained by analysis of variance and *D*-values obtained by Tukey's method (Snedecor, 1956) are shown in Table 4. The *F*-value is a statistic which indicates whether there are significant differences between measurements in a series, but it does not indicate where the differences exist. The *D*-value is derived from data computed for the analysis of variance test. It represents the value at or above which the

difference between any two measurements differs significantly at the 5 per cent level of confidence. By applying the *D*-values to the mean measurements, one may determine at what age a particular measurement reaches adult size.

A major limitation to this method of determining the age at which growth is complete is that the oldest age group represented may not accurately reflect upper size limits. No age at growth completion was derived for males because of the possibility that males at 5½ years may still be growing and because no data were available for males at 4½ and from 6½ to 9½ years.

For females, however, it was assumed that adult size had been attained when there was no significant difference between the mean for a given year and that for 10½+ years. Thus, for hind foot width, fore foot width, ear length and tail length, adult size is apparently attained by 1½ years, since there was no significant difference between the means for 1½ and 10½+ years. For head length, total length, neck circumference, upper canine length and upper canine width, adult size is attained by 2½ years. Between 1½ and 10½+ years, the mean total length increased 19.7 per cent, mean head length 16.2 per cent, mean upper canine length 18.2 per cent and mean upper canine width 33.3 per cent.

The growth curves in Figure 2 illustrate the great difference in size between adult males and females. The curve for females shows a gradual decline in growth rate from ½ to 5½ years and a leveling off between 5½ and 10½+ years, although few data were available for 3½-year-old females. The curve for males parallels that for females from 1½ to 2½ years, although the mean measurements were already larger. Then, instead of breaking at 2½ years, it continues at about the same rate until 3½ years. Unfortunately, data for males at 4½ years and from 6½ to 9½ years were lacking, so that the pattern of the curve after 5½ years is unknown. The 10½+-year-old males were larger in several dimensions than the 5½-year-old males. However, until the growth rate of males levels off and parallels that for females, the two sexes would continue to grow apart in size.

The only significant size differences between males and females at 1½ years were in hind foot width and fore foot width. At 2½ years, such differences included head length and upper canine width as well as hind foot and fore foot width. The only additional difference at 10½+ years was in total length.

A semi-log plot of mean total length against age showed growth to be curvilinear, as is true for most animals. Since growth is curvilinear, the growth rate is greatest in the younger age groups, and the greatest differences in size occur between the means for these age groups. As the growth rate levels off, no yearly differences between means are apparent.

TABLE 2. MEAN BODY MEASUREMENTS AND MEAN LIVE WEIGHTS OF FEMALE BLACK BEARS*

Measurement	Age (years) † ½ Number	½ Mean	½ Standard error	1½ Number	1½ Mean	1½ Standard error	2½ Number	2½ Mean	2½ Standard error	3½ Number	3½ Mean	3½ Standard error
Hind foot width	5	2.44	0.10	9	3.14	0.14	7	3.38	0.05	2	3.44	
Fore foot width	5	2.64	0.08	9	3.50	0.13	7	3.55	0.08	2	3.75	
Ear length	4	3.81	§	9	4.68	0.08	7	4.93	0.09	2	4.62	
Head length	5	7.38	0.26	9	10.57	0.37	7	11.53	0.14	2	11.31	
Total length	5	29.85	1.30	8	45.31	1.96	7	51.82	0.56	2	51.38	
Tail length	5	2.26	0.08	9	3.51	0.14	7	3.93	0.26	2	3.88	
Neck circumference	4	11.41	§	8	15.38	0.99	7	18.61	0.55	2	19.12	
Shoulder height	..	..	..	3	22.00	§	5	25.55	0.90	1	27.50	
Upper canine length	3	9	§	8	22	1.0	7	24	0.7	2	24	
Upper canine width	3	6	§	8	12	1.1	7	14	0.3	2	14	
Live weight	5	28	5.1	9	84	12.1	7	127	9.6	2	122	

Measurement	Age (years) † 4½ Number	4½ Mean	4½ Standard error	5½ Number	5½ Mean	5½ Standard error	6½ Number	6½ Mean	6½ Standard error	7½ Number	7½ Mean	7½ Standard error
Hind foot width	6	3.29	0.14	7	3.43	0.09	5	3.13	0.09	2	3.25	
Fore foot width	6	3.65	0.09	7	3.66	0.07	5	3.60	0.10	2	3.50	
Ear length	6	4.88	0.06	7	5.04	0.04	5	4.83	0.05	2	4.88	
Head length	6	11.62	0.18	7	11.79	0.07	5	11.58	0.22	2	12.25	
Total length	6	52.54	0.88	7	55.14	0.62	4	51.75	§	2	54.25	
Tail length	6	3.62	0.33	7	3.46	0.32	5	3.75	0.16	2	3.75	
Neck circumference	6	19.10	1.01	7	20.86	0.91	4	17.18	§	2	24.75	
Shoulder height	2	28.00	§	2	27.75	§	3	26.42	§	1	26.00	
Upper canine length	6	24	1.2	7	26	0.8	5	26	1.0	2	25	
Upper canine width	6	15	0.4	7	15	0.6	5	16	0.2	2	16	
Live weight	6	128	17.9	7	178	21.3	5	123	7.9	2	214	

Table 2. *(Continued)*

Measurement	Age (years) †								
	8½			9½			10½ and over ‡		
	Number	Mean	Standard error	Number	Mean	Standard error	Number	Mean	Standard error
Hind foot width	6	3.40	0.08	1	3.25	§	9	3.57	0.17
Fore foot width	6	3.60	0.09	1	3.12	§	9	3.76	0.12
Ear length	6	4.92	0.12	1	5.00	§	9	4.92	0.07
Head length	6	12.08	0.08	1	11.00	§	9	12.28	0.13
Total length	6	55.50	1.20	1	54.50	§	9	54.22	0.74
Tail length	6	4.48	0.28	1	3.00	§	9	2.89	0.25
Neck circumference	6	19.40	0.40	1	17.32	§	7	20.53	0.29
Shoulder height	4	25.19	§	1	27.00	§	2	26.75	§
Upper canine length	4	28	§	1	28	§	8	26	1.1
Upper canine width	4	17	§	1	16	§	8	16	0.6
Live weight	6	143	6.5	1	110	§	9	187	19.1

* All measurements in inches, except those for upper canine length and width (millimeters) and those for weight (pounds).

† At time of first capture (see text); therefore, some age groups are represented by a greater number of specimens than shown in Table 1.

‡ Includes specimens up to 16½ years old.

§ Not calculated when number of specimens was less than five.

TABLE 3. MEAN BODY MEASUREMENTS AND MEAN LIVE WEIGHTS OF MALE BLACK BEARS*

Measurement	Age (years) † ½ Number	½ Mean	½ Standard error	1½ Number	1½ Mean	1½ Standard error	2½ Number	2½ Mean	2½ Standard error	3½ Number	3½ Mean	3½ Standard error
Hind foot width	2	2.50	§	10	3.48	0.10	11	3.74	0.09	7	3.93	0.09
Fore foot width	2	2.84	§	10	3.79	0.08	11	4.02	0.08	7	4.34	0.14
Ear length	2	3.78	§	10	4.89	0.13	11	5.00	0.09	6	5.23	0.10
Head length	2	8.31	§	10	10.88	0.27	11	12.23	0.16	7	12.84	0.25
Total length	2	30.97	§	10	48.28	1.13	11	54.36	1.54	7	58.89	1.40
Tail length	2	2.44	§	10	3.68	0.24	11	4.02	0.09	7	3.77	0.37
Neck circumference	1	10.24	§	8	16.78	0.83	11	20.24	0.64	4	22.04	§
Shoulder height	..	..	..	3	23.08	§	6	26.96	0.60	2	29.00	§
Upper canine length	..	..	..	8	22	0.8	11	26	0.7	5	27	1.0
Upper canine width	..	..	..	8	12	0.8	11	16	0.6	5	17	0.9
Live weight	3	33	§	10	107	12.2	11	159	18.0	6	202	17.3

Measurement	Age (years) † 4½ Number	4½ Mean	4½ Standard error	5½ Number	5½ Mean	5½ Standard error	6½ Number	6½ Mean	6½ Standard error	7½ Number	7½ Mean	7½ Standard error
Hind foot width	2	3.69	§	5	3.85	0.16	3	3.75	§	1	4.25	§
Fore foot width	2	4.12	§	5	4.30	0.17	3	4.25	§	1	5.00	§
Ear length	2	5.00	§	5	5.10	0.13	4	5.16	§	1	5.50	§
Head length	2	12.88	§	4	13.25	§	3	12.75	§	1	14.50	§
Total length	2	58.00	§	5	59.25	1.95	4	61.75	§	1	66.50	§
Tail length	2	4.62	§	5	4.52	0.18	4	3.81	§	1	3.75	§
Neck circumference	1	22.05	§	4	21.73	§	3	24.93	§	..	..	..
Shoulder height	..	..	..	2	34.12	§	..	..	..	..	..	..
Upper canine length	1	32	§	3	31	§	3	28	§	1	34	§
Upper canine width	1	21	§	3	19	§	3	17	§	1	22	§
Live weight	2	192	§	4	183	§	4	236	§	1	332	§

Table 3. *(Continued)*

Measurement	Age (years) †								
	8½			9½			10½ and over ‡		
	Number	Mean	Standard error	Number	Mean	Standard error	Number	Mean	Standard error
Hind foot width	1	4.00	§	..	..	..	6	4.21	0.18
Fore foot width	1	4.50	§	..	..	..	6	4.46	0.24
Ear length	1	5.25	§	..	..	..	5	5.13	0.18
Head length	1	13.50	§	..	..	..	6	13.96	0.40
Total length	1	63.50	§	..	..	..	5	62.75	1.89
Tail length	1	5.50	§	..	..	..	6	3.73	0.20
Neck circumference	1	24.80	§	..	..	..	3	27.50	§
Shoulder height	1	31.00	§	..	..	..	3	31.58	§
Upper canine length	1	34	§	..	..	..	6	28	1.6
Upper canine width	1	19	§	..	..	..	6	20	0.6
Live weight	1	218	§	..	..	..	6	298	18.5

* All measurements in inches, except those for upper canine length and width (millimeters) and those for weight (pounds).

† At time of first capture (see text); therefore, some age groups are represented by a greater number of specimens than shown in Table 1.

‡ Includes specimens up to 32½ years old.

§ Not calculated when number of specimens was less than five.

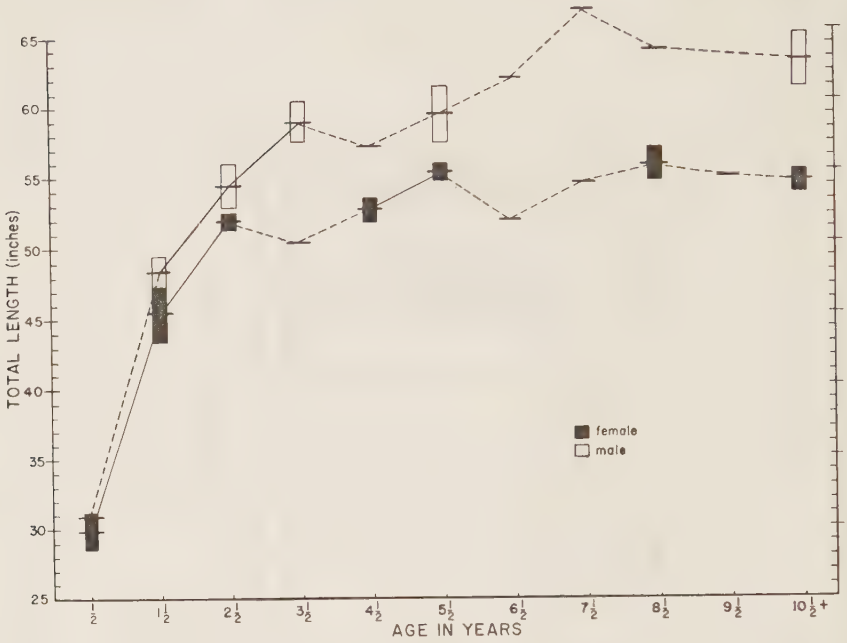

Figure 2. Comparison of mean total length at different ages for male and female black bears. Vertical bars represent magnitude of standard error (omitted when number of specimens was less than five).

TABLE 4. ANALYSIS OF VARIANCE FOR MEAN BODY MEASUREMENTS OF BLACK BEARS AND AGE AT WHICH THE DIFFERENT MEASUREMENTS REACH ADULT SIZE FOR FEMALES

	Female			Male§	
Measurement	*F*-value	*D*-value	Age at adult size†	*F*-value	*D*-value
Hind foot width	6.44**	0.58	1½	5.19**	0.46
Fore foot width	9.30**	0.49	1½	4.59**	0.52
Ear length	2.20	..	1½	1.20	..
Head length	47.09**	1.03	2½	23.32**	0.92
Total length	49.66**	5.22	2½	12.94**	6.28
Tail length	6.26**	1.15	1½	1.78	..
Neck circumference	24.85**	3.27	2½	..	..
Upper canine length	3.30*	4.2	2½	5.66**	3.6
Upper canine width	4.67**	3.0	2½	25.16**	2.3
Live weight	10.58**	70.4	2½	20.61**	61.0

§ Data for males insufficient for determining age at which adult size is reached.

† For each measurement, derived from Table 2 as the age whose mean is not exceeded by the mean for any subsequent age by more than the *D*-value.

* Significant at the 5 per cent level of confidence.

** Significant at the 1 per cent level of confidence.

For this reason, standard body measurements cannot be used to age bears.

For females, significant differences existed between cubs and yearlings for all five measurements for which data were adequate, i.e., hind foot width, fore foot width, head length, total length and tail length. Between 1½- and 2½-year-old females, a significant difference existed only for total length.

For males, significant differences existed between 1½- and 2½-year-old bears for head length, neck circumference, upper canine length and upper canine width. However, overlap in standard deviation was great enough to preclude judging age by any of these measurements except head length. By classifying animals with a head length of 11.50 inches or more as at least 2½ years old, it was possible to separate eleven 2½ year olds from seven of ten 1½ year olds. Further investigation of this difference would be desirable as it might provide a means of identifying yearling males.

WEIGHT

Mean live weights are included in Tables 2 and 3, and the weight data for each sex at different ages are plotted in Figure 3. Correlation

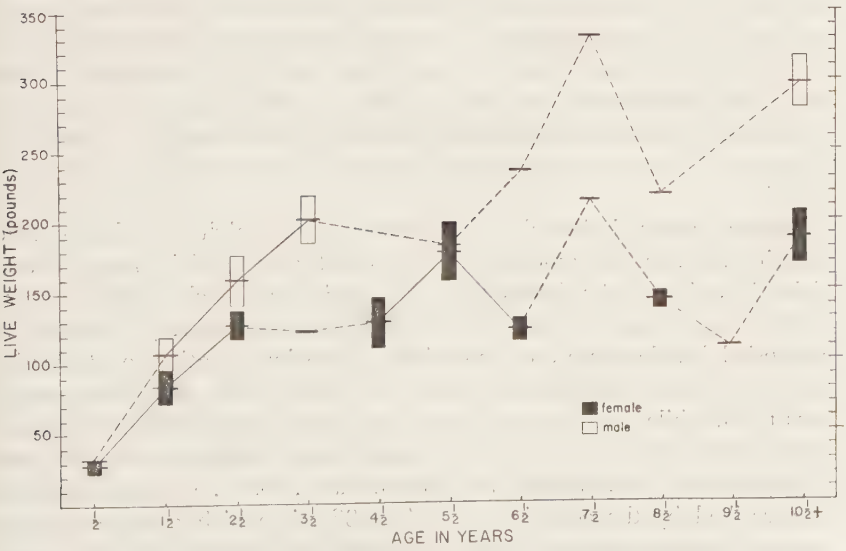

Figure 3. Comparison of mean live weight at different ages for male and female black bears. Vertical bars represent magnitude of standard error (omitted when number of specimens was less than five).

of weight with age for bears 2½ years old or older was significant at the 5 per cent level of confidence for females, and at the 1 per cent level for males. Among females, weight was extremely variable, with standard deviations as large as one-third of the mean. Mean weights for males followed a growth pattern similar to that of the other standard measurements. Among the males, there were significant differences in mean weight between 1½ and 3½ year olds, between 1½ and 10½+ year olds, and between 3½ and 10½+ year olds, but there was no significant difference between 2½ and 3½ year olds. The data suggest that females attain their adult weight by 2½ years but that males have not reached it by 3½ years.

Despite the correlation of weight with age, it is apparent that age is not the only influence on weight, as may be illustrated by the records for females. For all females 2½ years old or older, those captured in June, July, August and September showed a progressive increase in weight that was significant at the 1 per cent level of confidence. The mean weight of 11 females captured in June was 135±28.8 pounds; of 16 captured in July 131±29.5 pounds; of 21 captured in August, 190±72.8 pounds; and two captured in September weighed 150 and 155 pounds. The average lean weight of female bears at 2½ years of age was 130 to 135 pounds with a standard deviation of approximately 30 pounds. However, when bears start glutting themselves in late summer and fall, there may be a pronounced gain in weight which is then largely lost while they are in hibernation and during the following spring. There were actual records for only one female to support this hypothesis. Originally trapped on August 12, 1957, she weighed 239 pounds; retrapped in 1958, she weighed 155 pounds on June 28 and 161 pounds on July 10. The heaviest female examined, captured on August 15, 1957, weighed 361 pounds and was estimated by the tooth-sectioning method to have been 9½ years old. Presumably, males follow a seasonal trend in weight similar to that for females.

Among factors influencing the percentage of weight loss due to field dressing are age, sex, amount of gut content, among of fat removed and delay in weighing the dressed carcass (Hewitt and Black, 1959). Heavier animals lose a smaller percentage of weight during dressing. Data for 31 autopsied females were used to derive a regression equation for determining live weight from dressed weight for female bears only. Live weight was taken while the bear was under anesthesia. Dressed weight was taken of the bled carcass with the heart, lungs, kidneys, other viscera and loose intraperitoneal fat removed (Hewitt and Black, 1959). The regression line is described by the equation $y = -4 + 0.86x$, in which x represents live weight. Because weight is highly correlated with age and sex, the regression line for males undoubtedly has a different slope than that for females.

Standard Skull Measurements

Skull measurements were analysed for females in age groups 1½, 2½, 3½, 4½, 5½, 6½ and 8½ (Table 5) and for males in age groups 1½, 2½, 3½, 5½ and 10½ (Table 6). No cub skulls of known sex were available, and the numbers of 7½-year-old females and 4½-year-old males were too small for analysis beyond noting the means. Analysis of growth rate (Table 7) was treated in the same manner as described for standard body measurements. Growth curves for condyle-premaxillae length and for mastoid breadth are shown in Figures 4 and 5, respectively. Mastoid breadth, plotted on semilogarithmic paper, followed a curvilinear regression similar to the semilog curve for total body length.

For females, length of the maxillary molar series reaches a maximum as soon as the permanent molars are fully erupted at about 6 to 7 months. Adult size for postorbital breadth and cranial breadth is attained by 1½ years. Adult size for skull length is attained by 3½ years. The skull continues to grow in width, and for width measurements adult size is attained by 4½ years except for the least interorbital constriction and width of nasals. Between 1½ and 8½ years, the five measurements of skull length increased 24 to 26 per cent, while zygomatic breadth, mastoid breadth and least interorbital constriction increased 30 to 33 per cent, and both length and width of nasals increased 30 per cent. Other size increases were less striking.

At 1½ years, the skulls of males are significantly larger than those of females in all dimensions except postorbital breadth and least interorbital constriction. Curves for both sexes break at 2½ years, and they remain virtually parallel from 1½ through 3½ years, skulls of males being significantly larger.

Rausch (1961) found that, among black bears in Alaska, skull size and dentition were larger for males than for females. Ashton (1957), working with gorillas, found that the male skull becomes significantly larger than that of the female with the eruption of the permanent canines and third molars. If the same trend is present in black bears, significant differences in measurement between male and female skulls could occur at as early as 9 months when the permanent canines erupt. Then, if growth rates remained the same for the two sexes after 9 months, male skulls would continue to be significantly larger than female skulls.

None of the skull measurements could be used to age bears. Significant differences existed between the means for 1½- and 2½-year-old females for all measurements except postorbital breadth, cranial breadth and length of maxillary molar series. No significant differences existed between the means at 2½ and 3½ years. Moreover, the rapid decline in growth rate precludes the use of skull measurements to separate succes-

Table 5. Mean Skull Measurements of Female Black Bears*

Measurement	Age (years)								
	1½			2½			3½		
	Number	Mean	Standard error	Number	Mean	Standard error	Number	Mean	Standard error
Condyle-premaxillae length	6	203	6.7	8	229	2.8	6	236	5.4
Greatest length of skull	6	180	6.2	8	206	2.5	6	214	4.6
Basal length	6	189	6.1	8	215	2.6	6	222	5.4
Condylobasilar length	5	196	7.4	8	225	2.9	6	232	5.1
Boone and Crockett Club length	5	210	8.8	8	241	2.9	6	251	5.7
Zygomatic breadth	5	116	4.4	8	135	2.7	6	139	3.6
Postorbital breadth	7	61	1.4	7	62	1.8	6	62	0.8
Cranial breadth	7	84	0.9	8	85	1.2	5	85	1.0
Least interorbital constriction	7	47	1.4	8	52	0.9	6	53	1.1
Mastoid breadth	7	86	2.9	8	100	2.0	6	104	2.9
Greatest width across upper molars	7	60	0.5	8	62	0.6	6	62	1.4
Depth of cranium	7	85	1.8	6	91	1.6	5	92	1.9
Palatal length	6	106	3.4	7	119	1.3	6	124	3.0
Length of nasals	6	50	1.2	8	60	1.0	6	62	1.8
Width of nasals	6	20	0.4	8	22	0.5	6	22	0.8
Length of mandible	7	147	3.4	8	163	2.4	6	169	3.8
Length of maxillary tooth row	5	80	1.8	8	85	0.7	6	87	2.1
Length of maxillary molar series	6	38	0.6	8	38	0.5	6	39	0.7
Length of mandibular tooth row	6	92	1.7	8	98	0.4	6	100	2.0

Table 5. *(Continued)*

Measurement	Age (years)								
	4½			5½			6½		
	Number	Mean	Standard error	Number	Mean	Standard error	Number	Mean	Standard error
Condyle-premaxillae length	10	240	2.6	7	244	2.4	5	241	1.2
Greatest length of skull	10	217	2.5	6	219	2.9	4	218	§
Basal length	10	227	2.5	6	229	2.1	5	226	1.2
Condylobasilar length	8	237	3.2	5	238	2.7	5	237	1.2
Boone and Crockett Club length	10	254	3.4	6	257	2.8	4	257	§
Zygomatic breadth	10	145	1.6	6	154	1.9	5	148	1.2
Postorbital breadth	10	63	0.6	8	63	1.0	5	60	1.0
Cranial breadth	10	86	0.7	8	86	1.0	4	86	§
Least interorbital constriction	10	56	0.8	8	56	1.1	5	57	0.8
Mastoid breadth	10	108	1.8	7	111	1.9	5	112	1.2
Greatest width across upper molars	10	64	0.8	8	65	0.9	5	64	0.6
Depth of cranium	10	94	1.0	7	97	2.8	4	95	§
Palatal length	10	126	1.4	8	127	1.4	5	124	0.9
Length of nasals	10	63	1.1	8	65	1.6	5	62	1.0
Width of nasals	10	24	0.3	8	24	0.4	5	25	0.5
Length of mandible	8	172	2.3	6	175	2.1	4	174	§
Length of maxillary tooth row	10	88	1.2	8	90	0.5	5	88	0.8
Length of maxillary molar series	10	39	0.6	8	38	0.4	5	39	0.4
Length of mandibular tooth row	10	101	1.2	8	103	0.7	5	103	1.2

Table 5. *(Continued)*

Measurement	Age (years)					
	7½			8½		
	Number	Mean	Standard error	Number	Mean	Standard error
Condyle-premaxillae length	3	247	§	5	251	1.4
Greatest length of skull	3	224	§	5	226	1.8
Basal length	3	232	§	6	234	2.1
Condylobasilar length	3	242	§	5	246	1.5
Boone and Crockett Club length	3	260	§	4	262	§
Zygomatic breadth	3	150	§	6	153	1.5
Postorbital breadth	3	64	§	6	64	1.4
Cranial breadth	3	89	§	6	87	0.2
Least interorbital constriction	3	58	§	6	61	1.5
Mastoid breadth	3	113	§	5	114	1.0
Greatest width across upper molars	3	62	§	6	66	0.6
Depth of cranium	3	97	§	5	100	0.6
Palatal length	3	130	§	6	130	1.9
Length of nasals	3	66	§	5	65	2.2
Width of nasals	3	25	§	5	26	0.7
Length of mandible	3	174	§	5	178	1.5
Length of maxillary tooth row	3	89	§	6	92	1.1
Length of maxillary molar series	3	37	§	6	40	0.4
Length of mandibular tooth row	3	103	§	6	105	1.2

* All measurements in millimeters.

§ Not calculated when number of specimens was less than five.

Table 6. Mean Skull Measurements of Male Black Bears*

Measurement	Age (years) 1½ Number	1½ Mean	1½ Standard error	2½ Number	2½ Mean	2½ Standard error	3½ Number	3½ Mean	3½ Standard error
Condyle-premaxillae length	7	229	3.7	7	259	5.7	16	265	3.0
Greatest length of skull	10	203	3.5	10	237	5.4	20	240	2.6
Basal length	9	211	4.3	7	240	6.3	15	251	3.0
Condylobasilar length	7	225	3.7	6	251	5.6	14	260	3.3
Boone and Crockett Club length	10	237	4.3	10	276	5.8	19	281	3.0
Zygomatic breadth	11	130	2.4	8	152	4.9	22	159	1.9
Postorbital breadth	11	63	1.0	10	66	0.8	22	66	0.7
Cranial breadth	11	86	0.5	10	91	0.9	22	90	0.5
Least interorbital constriction	11	50	0.9	10	59	1.1	23	61	0.9
Mastoid breadth	10	94	1.8	9	114	3.3	18	119	0.5
Greatest width across upper molars	11	65	0.8	10	69	1.2	23	69	0.7
Depth of cranium	11	92	1.1	10	103	2.1	22	107	1.3
Palatal length	11	119	2.0	10	137	3.0	23	139	1.3
Length of nasals	11	61	1.4	10	66	1.3	23	68	1.1
Width of nasals	11	22	0.6	10	26	0.4	22	26	0.5
Length of mandible	11	162	2.5	10	185	3.5	21	189	1.7
Length of maxillary tooth row	11	88	0.9	10	96	1.8	23	96	1.0
Length of maxillary molar series	11	42	0.6	10	42	0.7	23	41	0.4
Length of mandibular tooth row	11	102	1.1	10	111	2.1	22	111	1.0

Table 6. *(Continued)*

Measurement	Age (years)								
	4½			5½			10½		
	Number	Mean	Standard error	Number	Mean	Standard error	Number	Mean	Standard error
Condyle-premaxillae length	4	265	§	5	281	6.4	5	275	2.9
Greatest length of skull	3	238	§	6	259	5.6	5	253	2.6
Basal length	4	249	§	5	267	5.2	5	261	2.3
Condylobasilar length	4	260	§	5	275	6.2	5	268	3.6
Boone and Crockett Club length	4	278	§	6	299	6.0	5	293	2.8
Zygomatic breadth	3	161	§	6	174	3.9	5	182	2.0
Postorbital breadth	4	66	§	5	67	1.3	7	65	1.4
Cranial breadth	3	90	§	5	90	1.1	5	90	1.1
Least interorbital constriction	4	62	§	7	65	1.4	7	65	1.1
Mastoid breadth	4	120	§	6	133	3.2	5	140	2.0
Greatest width across upper molars	3	72	§	7	71	1.1	7	72	1.4
Depth of cranium	3	108	§	6	111	2.0	6	110	1.5
Palatal length	3	134	§	6	145	2.4	7	142	1.2
Length of nasals	3	69	§	7	75	2.2	7	72	1.8
Width of nasals	4	27	§	7	28	0.8	7	29	1.0
Length of mandible	4	187	§	5	197	2.7	7	195	2.0
Length of maxillary tooth row	4	97	§	7	102	1.9	7	98	0.8
Length of maxillary molar series	4	41	§	7	43	0.8	7	41	0.5
Length of mandibular tooth row	4	112	§	7	116	1.8	7	113	0.9

* All measurements in millimeters.

§ Not calculated when number of specimens was less than five.

TABLE 7. ANALYSIS OF VARIANCE FOR MEAN SKULL MEASUREMENTS OF BLACK BEARS AND AGE AT WHICH THE DIFFERENT MEASUREMENTS REACH ADULT SIZE FOR FEMALES

Measurement	Female			Male§	
	F-value	*D*-value	Age at adult size†	*F*-value	*D*-value
Condyle-premaxillae length	15.77**	17	3½	18.10**	19
Greatest length of skull	18.16**	16	3½	24.20**	18
Basal length	16.60**	16	3½	23.95**	19
Condylobasilar length	14.15**	18	3½	16.97**	19
Boone and Crockett Club length	14.05**	19	3½	24.99**	20
Zygomatic breadth	20.18**	12	4½	37.66**	13
Postorbital breadth	0.78	..	1½	1.70	..
Cranial breadth	1.19	..	1½	6.81**	4
Least interorbital constriction	14.44**	5	6½	20.76**	5
Mastoid breadth	16.32**	10	4½	48.93**	10
Greatest width across upper molars	4.47**	4	4½	6.42**	4
Depth of cranium	8.33**	8	4½	20.36**	7
Palatal length	23.10**	9	3½	5.70**	8
Length of nasals	10.82**	7	2½	10.28**	6
Width of nasals	16.99**	2	6½	13.64**	3
Length of mandible	15.80**	12	3½	27.79**	11
Length of maxillary tooth row	7.62**	6	3½	13.05**	6
Length of maxillary molar series	0.69	..	½	0.76	..
Length of mandibular tooth row	7.13**	7	3½	10.64**	6

§ Data for males insufficient for determining age at which adult size is reached.

† For each measurement, derived from Table 6 as the age whose mean is not exceeded by the mean for any subsequent age by more than the *D*-value.

* Significant at the 5 per cent level of confidence.

** Significant at the 1 per cent level of confidence.

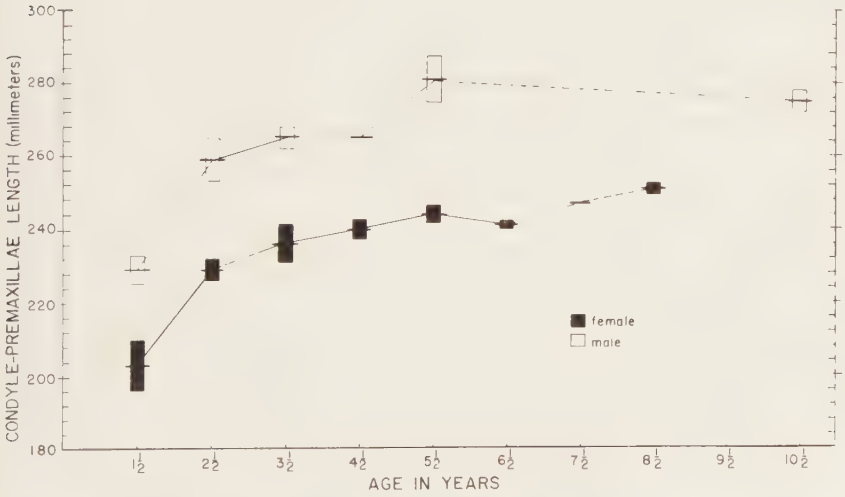

Figure 1. Comparison of mean condyle-premaxillae length at different ages for and female black bears. Vertical bars represent magnitude of standard error (omitted when number of specimens was less than five).

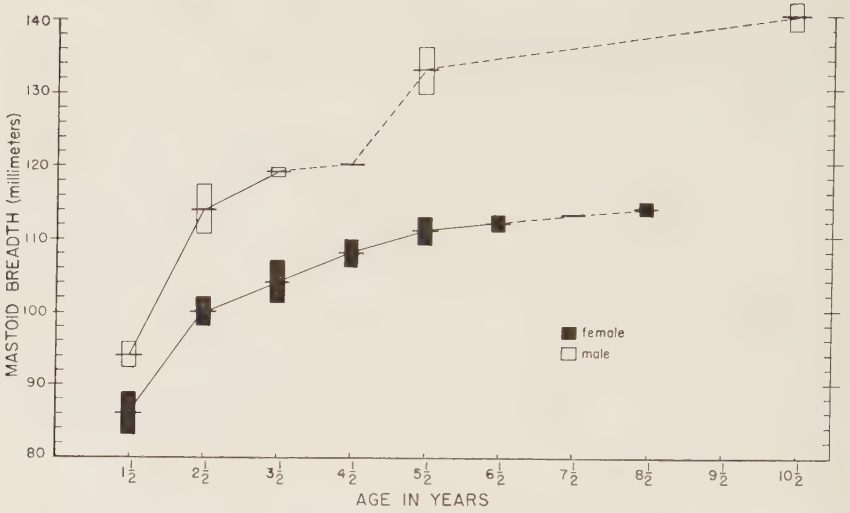

Figure 5. Comparison of mean mastoid breadth at different ages for male and female black bears. Vertical bars represent magnitude of standard error (omitted when number of specimens was less than five).

sive older age groups, even though there may be a significant difference between a 2½ year old and a 10½ year old.

The significant size difference between males and females for condylobasilar length, palatal length and length of mandible makes it possible to separate male skulls from female skulls with a minimum of concern about age groups. Animals can be separated into 1½-, 2½- and 3½-year-old or older age groups by the gross appearance of the canine root (Sauer et al., 1966). A dividing point in size at each of these ages was used to separate males from females (Table 8). Condylobasilar length

TABLE 8. MEASUREMENTS USED TO SEPARATE MALE AND FEMALE BLACK BEAR SKULLS

Measurement	Age (years)*						Age assignments correct (per cent)	
	1½		2½		3½ and older			
	Female	Male	Female	Male	Female	Male	Female§	Male§
Length of mandible	≦157	≧158	≦174	≧175	≦180	≧181	84 (57)	94 (54)
Palatal length ..	≦113	≧114	≦127	≧128	≦133	≧134	89 (61)	90 (57)
Condylobasilar length ...	≦208	≧209	≦244	≧245	≦248	≧249	92 (53)	93 (42)

* All measurements in millimeters.

§ Figures in parentheses represent number of specimens.

gave the highest degree of accuracy in separating these skulls, but the condyles and the back of the skull are often damaged. If a combination of the three measurements is used, a larger sample of skulls can be sexed. However, condylobasilar length should be given precedence when it can be measured. By using all three measurements, 55 of 58 male skulls (95 per cent) and 56 of 61 female skulls (92 per cent) were sexed correctly. Use of the lower canine teeth to distinguish sex has since been reported (Sauer, 1966) and is more precise if these teeth are available.

One male skull and one female skull were consistently sexed incorrectly, using all three measurements. Since these two specimens were included in establishing the limits for separating male and female skulls, the technique may be more accurate than it appears. Bergerud (1964) was able to successfully separate male and female caribou by mandible length when age was known.

Closure of Long Bones

The schedule of closure of the epiphyses of the long bones and of pelvic development is shown in Figure 6.

Female In the cub skeleton, the epiphyses are open on all long bones, and the ilium, ischium and pubis are separate. By 1½ years, the distal humerus may have started to close and the ischium and pubis are fused, but the ilium remains separate. By 2½ years, the distal humerus and the proximal radius are closed. The innominate bone is usually complete. A fourth bone at the junction of the ilium, ischium and pubis completes the acetabulum. From 3½ to 4½ years, the proximal ulna and the distal tibia start closing, and the distal radius and proximal femur may start to close. From 5½ to 6½ years, the proximal ulna and distal tibia close. Then there is a rapid closure period with all remaining epiphyses and the public symphysis exhibiting intermediate to final stages of closure. By 7½ years, all epiphyses except the proximal humerus are closed. The sacro-iliac articulation may begin closing. By 8½ years, the proximal humerus is usually closed. By 9½ years, the pubic symphysis is closed, and the ischial arch and ischial cartilages begin closing. Closure of the ischial cartilages appears to be complete by 15½ years. The sacro-iliac articulation is not complete by 16½ years. There are five vertebrae in the sacrum, and the first three eventually fuse with the ilium.

Male Unfortunately, data are scarce for males. By 3½ years, the distal humerus and proximal radius are closed. Whether these closures occur earlier is unknown. Data are too scant for determining pelvic development at 3½ years. At 4½ years, no additional epiphyses were closed in the few specimens available. On both the hind and fore feet of males 3½ to 4½ years old, the first phalanges are shaped to the claws and appear to have no epiphyses. One epiphysis is present at the proximal ends of the second and third phalanges. One epiphysis is present at the

Figure 6. Schedule of long-bone closure and pelvic development for male and female black bears.

distal ends of the metacarpals and metatarsals and at the proximal phalanx of digit I. Closure of these epiphyses is at an intermediate stage at 3½ to 4½ years. Also, closure of the epiphysis of the calcaneum and of the accessory carpal is at an intermediate stage at this time.

Compared with females at 3½ to 4½ years, males lag behind in closure of the proximal ulna and distal tibia. How long this lag continues cannot be determined precisely from present data. However, in one male at 10½ years and another at 13½ years of age, epiphyses of all long bones were closed.

Comparison With Other Species Rausch (1961) obtained femurs and humeri from 12 Alaskan black bears. Closure of the distal humerus was noted in a 6-year-old specimen, and growth of the femur and proximal humerus was assumed to be complete by 12 years. Order of epiphyseal closure was determined for black-tailed deer (*Odocoileus hemionus*) by Lewall and Cowan (1963), for European bison (*Bos bonasus*) by Koch (1935) and for man (*Homo sapiens*) by Stevenson (1924). The features most consistent in all are early closure of the distal humerus and proximal radius and late closure of the proximal humerus. There seems to be considerable variation in closure schedules for the remaining epiphyses. The foregoing authors found no indication of sexual differences in time of epiphyseal closure.

Looking for a standard of skeletal maturity in children, Todd (1937) took X-rays of male and female hands at 6-month intervals from birth to 18 years, 9 months. Until the ninth year, differences in closure were negligible, but from the thirteenth year on development was faster among the females. Closure of the distal radius and ulna occurred at 16 years, 3 months in females and at 18 years, 3 months in males.

One consistent feature of growth for individual bones is the later closing of the epiphysis at the end of the shaft that contributes most to increase in bone length (Weinmann and Sicher, 1947). Shape of the epiphyses usually makes the distinction obvious. For example, the proximal ulnar epiphysis consists solely of the tip of the olecranon process which contributes little to increase in the length of the shaft and closes earlier than the distal ulnar epiphysis.

It is generally considered that closure of the long bones marks the end of the subadult period of growth. Closure of the proximal humeral epiphysis was used to separate juveniles from adults for the cottontail rabbit (*Sylvilagus floridanus*) by Hale (1949), for the red fox (*Vulpes fulva*) by Reilly and Curren (1961) and for the lynx (*Lynx canadensis*) by Saunders (1964). In long-bone development, female black bears do not become adult until 8½ years of age.

It is not suggested that epiphyseal closure be considered as an aging technique. Todd (1937), working with children, found that nutrition could affect skeletal maturation by as much as two years, either positively

or negatively. Lewall and Cowan (1963) found that a low plane of nutrition could prolong life in black-tailed deer by 12 to 16 months at 5 years of age. Comparison of chronological age with physiological age as determined by epiphyseal closure might indicate an animal's level of nutrition during the period of bone growth.

Closure of Skull Sutures

The progress of closure for the major skull sutures is shown in Figure 7. In the cub skull, there are four occipital bones—a supraoccipital, two exoccipital and one basioccipital. Usually by 1½ years, these four bones have fused to form a single occipital bone surrounding the foramen magnum. The epiphyses on the occipital condyles are unfused in cub skulls but have fused by 1½ years.

From the author's observations, there is no interparietal bone in black bear skulls. The sagittal crest is formed from a portion of the supra-occipital bone between the parietals. Fusion of the occipital and interparietals occurs before birth in dogs and pigs (Sisson and Grossman, 1953), and this possibility exists for bears. Sisson and Grossman refer to the occipital bone in these animals as singular, so fusion of the four occipital elements apparently occurs before birth, which is not the case in bears.

Female From 2½ to 9½ years, the parieto-occipital suture begins to close along the sagittal crest. Before closure of this suture is complete, the basioccipital-basisphenoid and interparietal sutures generally close. From 9½ to 10½ years, there seems to be a rapid closure period. In all ten specimens 10½ years old or older, the parieto-occipital, basioccipital-basisphenoid, interparietal and maxillary-premaxillary sutures were closed. In all seven specimens 12½ year old or older, the interfrontal suture and the mastoid epiphyses were closed also. A second period of closure activity is suggested by a specimen 20½ years old with all sutures closed except the zygomatic-malar and maxillary-malar.

Male Order of closure is similar to that for females. In 13 specimens 9½ years old or older, the basioccipital-basisphenoid suture was closed. In nine specimens 12½ years old or older, the interparietal and maxillary-premaxillary sutures were closed, and in eight of these the parieto-occipital suture also was closed. In one male 20½-30½ years old, all sutures except the zygomatic-malar were closed. But in a male 25½ years old, only 12 sutures were closed, and in one 32½ years old only six sutures were closed.

Comparison With Other Species Schedules of skull-suture closure have been determined for human males (Todd and Lyon, 1924) and for 10 species of monkeys (Chopra, 1957). In general, closure begins with the vault sutures and progresses forward with the cranio-facial sutures fusing last. Young (1957) explained that closure is related

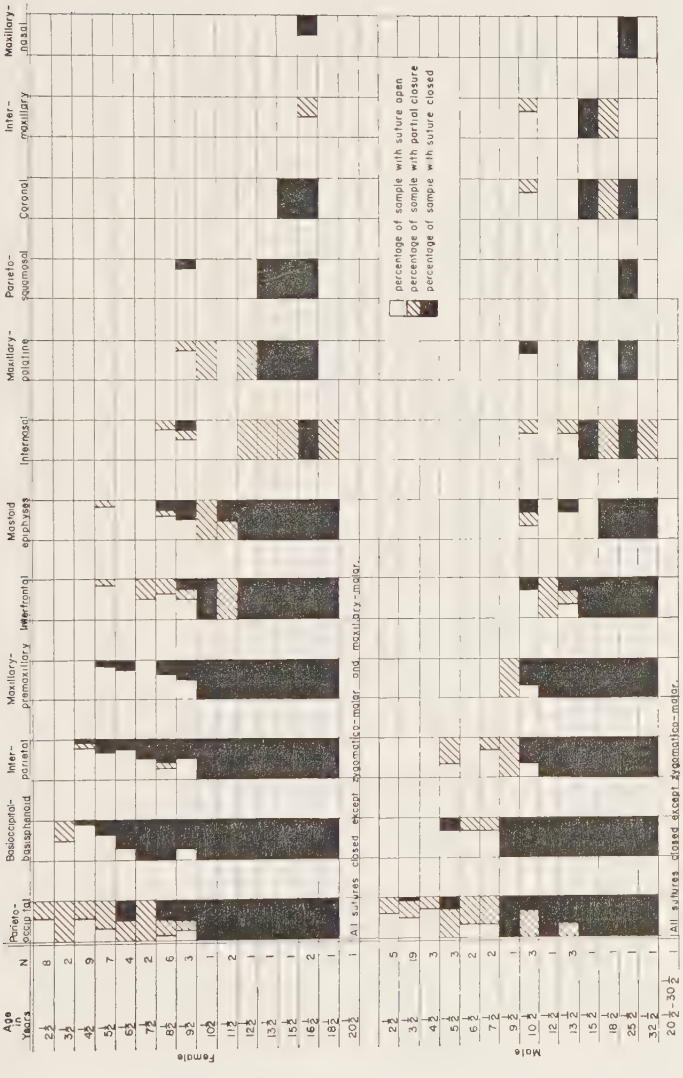

Figure 7. Schedule of skull-suture closure for male and female black bears.

to functional pressure. When the brain reaches maximum size, pressure on cranial bones ceases, growth stops and the cranial sutures close. Pressure from mastication develops facial bones, so facial sutures remain open longer. Closure in bears begins with the vault sutures except for the coronal suture, and growth of the braincase is complete by 1½ years. Facial and craniofacial sutures close before the circum-meatal sutures do.

Todd and Lyon (1924) found that the period of greatest activity in closure for human males occurred between 26 and 30 years. This period of suture closure does not occur until after attainment of skeletal maturity at 20 years (Stevenson, 1924). Subsidiary activity periods of suture closure occurred in the 50's and late 70's. Similar activity periods seem to occur for female black bears. The first such period occurs at 9½ to 10½ years, just after attainment of skeletal maturity at 8½ years, and the second occurs at about 20½ years.

Skull-suture closure has been used in combination with other characteristics to assign ages to mink *(Mustela vison)* (Greer, 1957), red foxes (Churcher, 1960) and otter *(Lutra canadensis)* (Hamilton and Eadie, 1964). But in most small mammals, sutures close too rapidly to be useful in assigning ages (Cain, 1962). Skull-suture closure cannot be used as an aging technique for black bears. Although there is a trend in suture closure, individual variation in time of closure is greatest before 10½ years, the period when yearly age assignments are most needed.

Reproduction

Reproductive data for 56 necropsied female black bears were published by Wimsatt (1963) using ages assigned by the tooth-wear method of Hewitt and Black (1959). Because of important differences between ages as determined by this method and the tooth-sectioning technique, data on ovarian analyses for 44 females as reported by Wimsatt are given in Table 9 together with the age of each animal as determined by both methods.

Wimsatt concluded that female black bears could become sexually mature at 1½ years because specimens A100 and A103 were assigned that age by the tooth-wear method, but he held his conclusions tentative pending development of a more accurate aging technique. The tooth-sectioning method is believed to be such a technique, and by it these specimens were found to be 3½ and 2½ years old, respectively. Differences in age assignments after 2½ years present no conflict with the remainder of Wimsatt's conclusions. Reproductive capacity is indicated through at least 16½ years. It is commonly believed that females reproduce every two years.

Wimsatt showed that, in New York, ovulation occurs during the last three weeks of June. The presence of large atretic follicles in 12 animals during the months of June and July is presented as evidence that ovula-

TABLE 9. SUMMARY OF REPRODUCTIVE DATA FOR FEMALE BLACK BEARS

Specimen No.	Age (years) Tooth-wear method*	Age (years) Tooth-sectioning method	Date taken	Ovarian analysis*
A35	cub	½	July 18	primary follicles only
A120	cub	½	August 27	primary follicles only
A101	1½	1½	June 14	small atretic follicles
A126	1½	1½	June 17	primary follicles only
A107	1½	1½	June 22	primary follicles only
A32	1½	1½	July 12	medium follicle, atretic
A103	1½	2½	June 18	1 large follicle (7mm.), atretic
A42	2½	2½	July 23	3 corpora lutea
A123	3½	2½	August 29	2 corpora lutea
A138	2½	2½	September 2	1 corpus luteum
A100	1½	3½	June 11	2 large follicles, 1 atretic
A39	2½	3½	June 29	medium follicle, atretic
A110	2½	4½	July 1	small follicles, atretic
A38A§	2½	4½	June 20	3 corpora lutea
A108	2½–3½	4½	June 23	3 large follicles, atretic
A119	2½	4½	August 25	primary follicles only
A121§	2½–3½	5½	August 27	4 corpora lutea
A28	1½–2½	5½	July 9	small follicles, atretic
A129	2½–3½	5½	July 15	2 large follicles, atretic
A114	3½	5½	July 24	small follicles, atretic
A38	3½–4½	5½	August 18	medium and small follicles, atretic
A132	2½–4½	6½	August 5	2 corpora lutea
A104	2½–4½	6½	June 22	2 large follicles, atretic
A40	7½	6½	July 10	2 corpora lutea
A131	2½–4½	6½	July 25	3 corpora lutea
A134	4½	6½	August 13	2 corpora lutea
A122†	4½	6½–10½	August 28	small follicles, atretic
A130	3½	7½	July 17	2 large follicles, atretic
A124§	4½	7½	August 30	3 corpora lutea
A117	2½–4½	8½	August 24	1 corpus atreticum
A127	5½+	8½	July 9	3 large follicles, atretic
A43	6½	8½	July 30	3 corpora lutea
A133	6½	8½	August 11	3 corpora lutea
A118§	3½	8½	August 22	4 corpora lutea
A34†	4½+	8½–10½	July 18	small follicles, atretic
A128	4½–5½	9½	July 11	3 large follicles, atretic
A105§	4½+	9½	June 22	2 corpora lutea
A44	8½	10½	August 5	2 corpora lutea
A33	4½+	11½	July 13	5 corpora lutea
A27	4½+	12½	June 23	2 corpora lutea
A109	4½+	13½	June 24	3 corpora lutea
A136	8½	13½	August 26	3 corpora lutea
A112	4½+	15½	July 9	3 large follicles, atretic
A115	4½+	16½	August 9	2 corpora lutea

* Data from Wimsatt (1963).

§ Free blastocysts recovered (Wimsatt, 1963).

† Could not be assigned a single age group. Therefore, because it was probably less than 10½ years old (i.e., the age below which the data were analyzed in terms of specific years), it is included as undetermined age in Table 1.

tion may not occur without coital stimulus. Unimplanted blastocysts were recovered in June, August and November, providing proof that implantation in black bears is delayed for a period of approximately 5 months.

Delayed implantation apparently occurs in the brown bear, grizzly bear

and polar bear, since reproduction patterns in these species are similar to those in the black bear (Hamlett, 1935). Regarding the mechanism of delayed implantation, both Nutting and Meyer (1963) and Shelesnyak and Kracier (1963) found that in rats a high level of progesterone is necessary for survival of the blastocyst before implantation and that an estrogen surge is necessary for nidation to take place. The latter authors also found that estrogens have a relationship to the histamine content of the uterus. Whether the blastocyst plays an active or passive role in the process of nidation is uncertain.

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COMPARISON OF THE BOTTOM FAUNA IN 1916 AND 1967 IN A BAY OF ONEIDA LAKE, NEW YORK[1]

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ABSTRACT

Quantitative studies of the bentic invertebrates of Lower South Bay (Oneida Lake) had been made in 1916 and were repeated in 1967. The number and frequency of occurrence of Tubificidae and Amphipoda were higher in 1967, while Ephemeroptera and Trichoptera had decreased significantly. Little change occurred in the total numbers of chironomids. Eutrophication and shoreline development were probably responsible for changes in the benthic community.

Oneida Lake is shallow (maximum depth, 16.8 meters; mean depth, 7.6 meters), drains a watershed of nutrient-rich soils (Greeson, 1971) and is fully exposed to prevailing winds. These conditions result in high biological production. Nuisance blooms of algae occur periodically and were the impetus for several studies of plankton, microbiology, and water chemistry and quality (Mt. Pleasant et al., 1961; Muenscher, 1928; Wagner, 1928). Greeson (1971) concluded from studies in 1967-1969 that the nutrient input from cultural sources was low, that the gross chemical composition of the lake had remained stable and that the natural eutrophic condition of the lake had not changed for many years.

In contrast, observations of the benthos suggest eutrophication. A dramatic decrease in numbers of burrowing mayflies (*Hexagenia*) and a concurrent increase in chironomid midges between 1956 and 1964 was attributed to oxygen depletions during periods of temporary thermal stratification (Jacobsen, 1966). Similar changes in the bottom fauna occurred during the accelerated eutrophication of Lake Erie (Beeton, 1961; Carr and Hiltunen, 1965). A marked decrease in diversity of the molluscan fauna of Oneida Lake is also suggestive of enriched conditions (Harman, 1968; Harman and Forney, 1970).

Because of its large size (207.2 square kilometers), its proximity to the Syracuse metropolitan area and its important sport fishery, Oneida Lake, when compared with most other lakes, has been studied extensively since early in the present century. Baker (1918) described the benthos of Lower South Bay in 1916 in one of the earliest quantitative studies conducted in North America. His detailed descriptions of sampling techniques and stations facilitated replication of his studies 51 years later. The present paper compares the benthos in 1916 and 1967, describes

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changes in composition and examines the significance of the changes as indications of eutrophication.

STUDY AREA AND METHODS

Lower South Bay, located in the southwestern section of Oneida Lake, is protected from the prevailing northwest winds. The area is 375 hectares, with a maximum depth of 5 meters. Most of the bottom deeper than 2 meters is mud. At the time of Baker's survey most of the shoreline was undisturbed, but by 1967 it was an array of cottages, boat liveries and docks. Greeson (1971) reported that the number of dwellings on Oneida Lake as a whole increased more than ninefold between 1900 and 1960.

In July 1916, Baker collected samples of bentic animals from 134 stations in Lower South Bay. He noted the type of bottom from which each collection was made and classified the sites as boulder, gravel, sand, clay, sandy-clay, shallow mud (less than 2 meters) and deep mud. Samples in water less than 2 meters deep were taken with a Walker dipper, a sieve flattened on one side to sample about 100 square centimeters. In deeper water, a large dredge (40.6 × 40.6 centimeters) was used to sample an area of approximately 5,000 square centimeters. Where the substrate was rubble, all invertebrates were picked from several boulders and the surface was estimated.

In July 1967, Baker's sites were relocated and sampled with the same types and sizes of collecting equipment, except that an Ekman dredge (225 square centimeters) was used in the deeper areas. The number of samples taken at each site was the same as in the 1916 study, but for purposes of analysis samples were pooled. Eleven of the original sites could not be found because of alterations of the shoreline. An additional eight had to be discarded because of unequal sampling effort in 1916 and 1967.

Organisms collected in 1967 were classified in major groups[2], and their occurrence and numbers were paired with the composition of the sample taken at the same location in 1916. These pairs of data were tested for significant differences according to type of organism (7 pairs) or type of bottom (10 or 12 pairs). A number of groups including Polyzoa, Cladocera, Copepoda, Ostracoda and Acarina, which were recorded by Baker, were not incorporated in this study since the method of sampling probably did not provide reliable estimates of abundance. Porifera and Opisthopora in samples were recorded but not counted. The data on Mollusca have already been reported (Harman and Forney, 1970) and are not considered here.

[2] John Forney made the collections in 1967, and Richard Noble identified the invertebrates and wrote a preliminary report on the findings (Noble, 1969).

RESULTS

Samples taken in 1967 contained about twice as many benthic invertebrates as those taken in 1916 (Table 1). Total numbers increased

Table 1. Number of Individuals of Various Benthic Invertebrates Taken on Different Bottom Types in Lower South Bay of Oneida Lake in 1916 and 1967

Invertebrate	Bottom type§							
	Boulder (10)	Gravel (7)	Sand (36)	Clay (26)	Sandy-clay (15)	Shallow mud (5)	Deep mud (16)	Total§ (115)
Turbellaria								
1916	8	0	0	2	16	0	2	28
1967	24	0	9	7	0	0	2	42
Hirundinea								
1916	5	0	5	6	12	1	8	37
1967	5	0	0	29	2	0	1	37
Naididae								
1916	21	66	416	185	91	32	23	834
1967	11	2	59	36	20	3	81	212
Tubificidae								
1916	1	30	34	35	9	9	13	131
1967	0	61	342	404	107	11	218	1,143*
Amphipoda								
1916	47	23	208	273	142	8	41	742
1967	675	345	1,733	1,303	726	139	40	4,961*
Isopoda								
1916	1	2	13	415	32	18	17	498
1967	1	1	26	6	3	1	2	40
Ephemeroptera								
1916	9	6	4	2	2	0	37	60
1967	2	0	1	1	0	0	0	4*
Trichoptera								
1916	82	28	134	149	32	10	146	581
1967	15	6	20	5	3	0	0	49*
Chironomidae								
1916	18	63	548	184	158	19	238	1,228
1967	179	194	534	283	315	29	147	1,681
Other†								
1916	1	7	18	21	18	0	8	73
1967	0	1	16	25	9	0	1	52
Total								
1916	193	225	1,380	1,272	512	97	533	4,212
1967	912	610	2,740	2,099	1,185	183	492	8,221

§ Figures in parentheses represent number of stations.

* Significant difference at 95 per cent level (Wilcoxon's signed rank test; Siegel, 1956).

† Decapoda, Megaloptera, Lepidoptera, Ceratopogonidae, Coleoptera.

on all bottom types except deep mud (more than 2 meters) where little change was detected. A sevenfold increase in amphipods was largely responsible for the rise in the total number or organisms. Tubificids were the only other group which showed a significant increase in numbers at all sites, with most of the gain occurring on sand, clay, sandy-clay and deep mud bottoms. In contrast, another group of oligochaetes, the Naididae, showed a marked decrease in numbers on sand and clay bottoms but an increase on deep mud bottoms.

Ephemeroptera and Trichoptera declined in numbers between 1916 and 1967, and the decrease was evident on all types of substrate. Isopoda were substantially less abundant in 1967, but the change was primarily the result of a sharp decline in clay areas. Chironomidae, which were the most abundant component of the community in 1916, showed a slight gain in numbers. Turbellaria and Hirudinea showed little overall change, and shifts in abundance on different substrates were inconsistent. Largely because of the marked unidirectional changes of some organisms on most or all bottom types, there were no significant overall changes in abundance of all organisms on any one substrate (Table 1).

Porifera occurred at 57 of the 115 stations in 1967, compared with 15 in 1916, suggesting a substantial extension of their distribution (Table 2). Opisthopora, which were not recorded in 1916, were found at over one-fourth of the stations in 1967. Except for the Naididae and for the shallow mud bottom type, changes in both total occurences and total numbers between 1916 and 1967 were in the same direction (Tables 1 and 2).

Several taxonomic groups underwent substantial changes in generic composition. The amphipod population in 1916 was 96 per cent *Hyalella*, but by 1967 it was primarily *Gammarus*. Four genera of mayflies (*Hexagenia*, *Heptagenia*, *Baetis* and *Caenis*) were found in 1916, but only *Caenis* was present in 1967. The chironomid *Procladius* was represented by only a single individual in 1916, but 77 individuals were found at 31 sites in 1967. Composition of the Trichoptera changed little; *Helicopsyche*, *Molanna*, hydroptilids, psychomyiids, and especially leptocerids were well represented in both years.

DISCUSSION

Since these data were derived from collections made in only one month of two widely separated years, much of the variation in results could be due to typical between-year variation or to failure to relocate the exact site. Timing of emergence of insects could have an especially pronounced effect. It has been shown that in shallow, eutrophic lakes, such as Sugarloaf Lake in Michigan, the kinds of benthic invertebrates

Table 2. Number of Stations in Lower South Bay of Oneida Lake, According to Bottom Type, at Which Various Benthic Invertebrates Were Taken in 1916 and 1967

Invertebrate	Bottom type§							Total§ (115)
	Boulder (10)	Gravel (7)	Sand (36)	Clay (26)	Sandy-clay (15)	Shallow mud (5)	Deep mud (16)	
Porifera								
1916	1	1	2	4	1	0	6	15
1967	2	2	18	18	10	3	4	57
Turbellaria								
1916	2	0	0	1	3	0	2	8
1967	6	0	3	6	0	0	2	17
Hirundinea								
1916	4	0	3	5	4	1	2	19
1967	1	0	0	6	2	0	1	10
Naididae								
1916	3	4	22	14	10	3	2	58
1967	6	1	20	12	7	3	13	62
Tubificidae								
1916	1	3	9	10	3	2	3	31
1967	0	4	33	25	11	3	16	92*
Opisthopora								
1916	0	0	0	0	0	0	0	0
1967	0	3	9	9	7	2	0	30
Amphipoda								
1916	3	4	19	17	15	4	7	69
1967	10	7	36	23	15	4	7	102
Isopoda								
1916	1	2	4	12	8	3	2	32
1967	1	1	4	5	3	1	2	17
Ephemeroptera								
1916	4	1	3	2	2	0	10	22
1967	1	0	1	1	0	0	0	3*
Trichoptera								
1916	8	4	27	11	10	4	15	79
1967	7	3	8	3	3	0	0	24*
Chironomidae								
1916	5	6	26	20	12	4	15	88
1967	8	7	34	21	15	3	16	104
Other†								
1916	1	4	11	10	8	0	4	48
1967	0	1	10	11	3	0	1	26
Total								
1916	32	25	115	96	68	21	74	xxx
1967	42	28	166	129	73	19	61	xxx

§ Figures in parentheses represent number of stations.
* Significant difference at 95 per cent level (Wilcoxon's signed rank test; Siegel, 1956).
† Decapoda, Megaloptera, Lepidoptera, Ceratopogonidae, Coleoptera.

and their abundance and distribution vary considerably between concurrent samples at several stations in a seemingly homogeneous area of a lake (Beatty and Hooper, 1958), and, at individual sites, between seasons (Anderson and Hooper, 1956) and between years (Schneider, 1965). Differences in sampling technique or ability in identifying organisms could also have contributed to the differences noted between 1916 and 1967. Because of these limitations, the organisms were combined into broad taxonomic groups, and the samples were combined to test only for gross differences between years and type of substrate.

Differences in abundance for the major taxonomic groups and changes in the species composition of these groups between 1916 and 1967 were those generally associated with increasing lake productivity. Tubificids are well adapted to low oxygen (Jónasson, 1969) and are often used as indicators of organic pollution (Surber, 1957).

Although some trichopterans are capable of tolerating a wide range of chemical factors (Roback, 1965), they, like the Ephemeroptera, are generally considered clean-water organisms, and their over-all decline in Lower South Bay may indicate a deterioration of water quality. Caddisfly larvae were largely eliminated by eutrophication in Lake Erie (Beeton, 1961; Carr and Hiltunen, 1965). Trichopterans were especially decimated in mud areas of Lower South Bay where the habitat may have been marginal.

In 1916, many of the mayflies found by Baker were *Hexagenia limbata,* the species which underwent a pronounced decline in the open areas of Oneida Lake from 1956 to 1964 (Jacobsen, 1966). No *Hexagenia* were seen in 1967, indicating that a similar change had occurred in Lower South Bay. The only mayfly present in 1967 was *Caenis,* a baetine genus that commonly survives pollution and, in streams, reappears below effluent outfalls well before ephemerids such as *Hexagenia* (Leonard, 1965).

On the other hand, no over-all increase in chironomids accompanied the disappearance of burrowing mayflies, as was the case in Oneida Lake proper (Jacobsen, 1966) and Lake Erie (Beeton, 1961; Carr and Hiltunen, 1965). Chironomids not only failed to increase significantly in 1967, but, since Baker did not count all chironomids, they were probably no more abundant, if as abundant, than in 1916. The genus *Procladius,* however, which increased substantially from 1916 to 1967, is considered indicative of pollution (Surber, 1957; Carr and Hiltunen, 1965). Although total numbers and occurrences of chironomids did not increase, there may have been a shift in composition to more tolerant forms. This could not be tested because Baker lumped many present genera of chironomids into the genus *Chironomus.*

Parallel changes in frequency of occurrence and numbers of organisms

appear to indicate that local environmental conditions and the density of individuals of most groups at any particular site did not change greatly from 1916 to 1967, but that a greater or lesser portion of Lower South Bay was generally suitable for occupation due to subtle environmental changes throughout the bay — changes such as might be caused by slow eutrophication. Physical alterations in Lower South Bay, however, cannot be ruled out as major causes of the differences in benthic invertebrates. Many of the sites classified as clay or sandy-clay by Baker were overlain with 2 to 3 centimeters of organic mud in 1967 (J. Forney, personal communication). These changes in the bottom could have been the result of shoreline developments such as filling, dredging and cottage building, as well as the result of increased organic production.

Changes in the benthic community of Lower South Bay were generally consistent with changes in the benthos of the open lake and the molluscan fauna. Organisms characteristic of highly eutrophic waters had replaced less tolerant forms. Although Greeson (1971) found no evidence of gross cultural eutrophication, shifts in land use, agricultural practices and intensified recreational use may have combined to produce a subtle increase in productivity which was sufficient to trigger changes in the benthic community. Whether eutrophication is continuing or has stabilized can only be determined through further studies.

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REPRODUCTION OF WHITE PERCH IN THE LOWER HUDSON RIVER[1]

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ABSTRACT

Information on reproduction of the white perch (*Morone americana*), derived from data collected between river miles 40 and 60 of the Hudson River estuary in 1972, is presented and compared with that in the published literature. The estimated average number of eggs spawned ranged from 20,676 for 3-year-old fish to 135,289 for 9-year-old fish. Among age II fish, less than 20 per cent of the males and none of the females were sexually mature. At age III, all males and 75 per cent of the females had reached sexual maturity. Spawning activity during 1972 was most intense in early June when water temperatures were between 18° and 20° C.

This paper presents baseline information on the reproductive potential of the white perch *(Morone americana)* population of the Hudson River estuary, as derived from data collected between river miles 40 and 60 in 1972. Continuing studies should provide a measure of the change (or lack of change) in the reproductive potential of this population following the placing in operation (by 1975) of two large nuclear generators in the study area. Knowledge of any changes that occur will aid in evaluating the effect of plant operation on the over-all population dynamics of the species.

Fecundity of white perch was described for 10 specimens from the Quabbin Reservoir in Massachusetts (Taub, 1969). Sheri and Power (1968) reported on the reproductive potential of the species in the Bay of Quinte on Lake Ontario. Conover (1958) made fecundity estimates for white perch collected in Albemarle Sound and the lower Roanoke River in North Carolina, but the fish examined may have been partially spent. Mansueti (1961) determined age at sexual maturity for white perch collected in the Patuxent Estuary in Maryland, but the number of eggs in gravid females was not reported. The present paper reports fecundity estimates, time and water temperature at the apparent peak of spawning activity, and the percentage of mature fish in age groups

[1] This investigation was part of an ecological study conducted by Texas Instruments, Inc. for the Consolidated Edison Company of New York. The authors wish to thank V. W. Kaczynski for reviewing the manuscript and offering useful suggestions. Daniel H. McKenzie and Thomas C. Cannon assisted in the statistical analyses.

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I to VIII as indicating the age of first reproduction. To our knowledge, no comprehensive investigation concerning the fecundity of white perch inhabiting a dynamic estuarine eco-system comparable to the lower Hudson River has previously been documented.

MATERIALS AND METHODS

White perch were collected between river miles 40 and 60 (from Stony Point in Rockland County north to the Beacon-Newburgh Bridge) from April to July in 1972. Collections were made with bottom and surface trawls, beach seines, trap nets, electroshockers and gill nets. The fish used in all aspects of the study were selected by a stratified random sampling procedure to adequately describe all ages and sizes.

The specimens were separated into three groups according to their capture location as follows:

Region I — miles 40–46
Region II — miles 46–56
Region III — miles 56–60

A regional analysis was used for several reasons. Region I was considered an experimental area in that one nuclear fuel and one fossil fuel electrical-power-generating facility had been operational since 1962 and 1949, respectively, and because at the time of the study two additional nuclear generators were under construction in that vicinity. Because the basin morphology of Region II was generally narrower and deeper, it was treated separately. Also, Region II was considered as a buffer zone, while Region III represented a control area. Data collected in Region III are also intended as baseline information regarding conditions prior to construction of the proposed pump-storage electrical-power-generating facility in that area.

To determine the fecundity of white perch, ovaries were removed from the female fish collected and stored in 10 per cent formalin. Ovaries were blotted "dry" and weighed. An analysis of variance for the number of eggs per gram in anterior, median and posterior aliquots of the right and left ovaries for an individual fish showed no significant differences ($P = .05$). Both the ovaries and aliquots were weighed to the nearest 0.01 gram with a triple-beam balance. The number of eggs in the weighed aliquot was counted and used to estimate the total number of eggs in the entire ovary. All eggs over 0.1 millimeter in diameter were counted, provided they had the appearance (opaque, yellow-white) of mature eggs. Appearance was used because no clear distinction between immature and mature eggs could be discerned using egg diameter or any other descriptive parameter. Correction factors were later calculated, using egg-retention values determined from ovaries collected after the spawning season. These procedures varied from those used by Sheri

and Power (1968) who reported finding eggs of three obviously different sizes in ovaries before spawning. They concluded that only the largest eggs would be spawned and included only them in fecundity estimates.

RESULTS AND DISCUSSION

Field observations indicated that the peak of white perch spawning in all three regions in 1972 occurred in June when water temperatures were 18° to 20° C. and salinity remained below 1.0 ppt. At this time, eggs and milt were easily extruded with minimal pressure on the abdomen. The flaccid condition of gonads observed in late June and July indicated cessation of spawning activity. Sheri and Power (1968) and Mansueti (1961) found white perch spawning activity to be most intense at water temperatures between 10° and 15° C. in the Bay of Quinte on Lake Ontario and in the Patuxent Estuary in Maryland, respectively.

Relationships between ovary weight and total body weight for 254 female white perch collected in the study area from April to July were determined (Table 1). Changes in the ratio of ovary weight to body weight, expressed as a percentage, confirmed that spawning occurred primarily in June. Ovary weight increased from April to May and decreased in June and July.

Table 1. Mean Ovary Weight, Expressed As Percentage of Body Weight, For Female White Perch Collected in the Hudson River in 1972*

Age (years)	April	May	June	July
2	..	..	3.26 (10)	4.27 (8)
3	2.80 (12)	6.49 (16)	5.71 (14)	2.20 (10)
4	2.58 (7)	6.44 (32)	4.41 (15)	2.09 (6)
5	2.44 (5)	6.91 (23)	4.52 (26)	2.36 (13)
6	2.12 (1)	6.52 (14)	4.40 (13)	1.77 (7)
7	..	..	4.10 (12)	1.33 (5)
8	..	..	2.53 (5)	..

* Figures in parentheses represent number of specimens.

Table 2. Percentage of Sexually Mature Fish Among White Perch Collected in the Hudson River in May of 1972*

Age (years)	Region I		Region II		Region III	
	Male	Female	Male	Female	Male	Female
2	16 (25)	0 (19)	13 (15)	0 (25)	20 (5)	0 (10)
3	100 (2)	75 (8)	100 (6)	67 (12)	100 (7)	75 (8)
4	100 (8)	100 (18)	100 (8)	100 (13)	100 (8)	100 (11)
5	100 (6)	100 (8)	100 (6)	100 (13)	100 (3)	100 (9)
6	100 (2)	100 (3)	100 (4)	100 (11)	100 (5)	100 (10)
7	..	..	100 (2)	100 (2)	..	100 (2)
8	..	..	100 (1)	..	..	..

* Figures in parentheses represent number of specimens.

During May, 295 white perch were examined, and the percentage of mature fish in each age group was determined. It was found that Mansueti's (1961) descriptions of ovary size and color were generally suitable criteria for categorizing stages of female maturity for white perch from the Hudson River study area. However, his definition of immature females was expanded to include females with developing ovaries that would not spawn during the same season. Little difficulty was encountered in separating immature from mature males on the basis of relative gonad size.

The percentages of sexually mature white perch collected during May were very similar for the three regional samples (Table 2). All males were mature by age III, while only 16, 13 and 20 per cent of age II males had reached sexual maturity in Regions I, II and III, respectively. Generally, females matured one year later than males. No age II and only 67 to 75 per cent of age III females were sexually mature. All females were mature by age IV. These findings were similar to those of Sheri and Power (1968) for white perch collected in the Bay of Quinte on Lake Ontario. With respect to the Patuxent Estuary in Maryland, however, Mansueti (1961) found that all age II males and a high percentage of the age II females had reached sexual maturity.

The higher percentage of mature 2-year-old fish reported by Mansueti (1961) was probably due to their faster growth. He demonstrated that the larger fish in an age group matured sooner. Growth data from the present study indicate that white perch of ages I, II and III from the Hudson River were noticeably shorter than their counterparts from the Patuxent Estuary.

Fecundity estimates were made for 87 female white perch collected in all three river regions during May and representing age groups III to IX. The relationship between total length and number of eggs present in the ovaries of these fish was exponential. Equations of the regression lines transforming the exponential relationship to a straight line for the three regions are expressed by the formula: $\log_{10}$ eggs $= a + b$, in which b is the total length. The regression equations (Table 3) were significantly different from zero ($P = .01$). Sheri and Power (1968) found that the

Table 3. Relationship Between Number of Eggs and Total Length For Female White Perch Collected in the Hudson River in May of 1972

Region	Number of specimens	Regression line formula	Correlation coefficient	F value
I	30	Log_{10} eggs $= 3.336 + 0.008$*	0.827	60.585
II	30	Log_{10} eggs $= 3.501 + 0.007$*	0.750	36.000
III	27	Log_{10} eggs $= 3.284 + 0.008$*	0.857	69.140

Table 4. Mean Calculated Total Length (in millimeters) At Annulus Formation For Female White Perch Collected in the Hudson River in 1972*

Age (years)	Region		
	I	II	III
3	162.1 (84)	160.3 (40)	157.5 (73)
4	184.2 (59)	184.9 (27)	178.4 (49)
5	194.8 (50)	190.6 (24)	194.4 (51)
6	202.1 (26)	203.7 (6)	208.1 (41)
7	215.3 (6)	213.2 (2)	222.2 (14)
8	213.3 (5)	255.3 (1)	209.2 (3)
9	240.2 (2)	..	231.0 (1)

* Figures in parentheses represent number of specimens.

Table 5. Number of Eggs Present in Ovaries of Female White Perch Collected in the Hudson River in May of 1972

Region	Age (years)						
	3	4	5	6	7	8	9
I	37,887	55,959	67,471	76,748	96,882	93,522	150,345
II	41,103	60,356	66,095	81,438	94,750	185,360	..
III	33,482	48,924	65,408	83,868	108,322	85,558	127,120

relationship between number of eggs and fork length for white perch also was curvilinear (correlation coefficient=0.82).

Calculated total lengths at annulus formation for the female white perch collected are given in Table 4. They were used in the regression equations to determine the number of eggs present in May for fish 3 to 9 years old (Table 5). Since annulus formation and spawning were generally coincidental for most white perch during 1972, the back-calculated total length at annulus formation closely approximated the total length at spawning.

Examination of the ovaries collected in July indicated that a correction factor due to egg retention after spawning was necessary to adjust fecundity estimates for fish collected in May. Such a factor was obtained by making egg counts for 58 white perch, ages III to VII, collected in July. The mean number of eggs retained in the ovaries in July, after spawning, and 95 per cent confidence intervals about the mean are presented in Table 6. Statistical analysis (hsd-test; Steele and Torrie, 1960) showed no significant differences (P=.05) between ages in the mean number of eggs retained for fish in the same region.

The number of eggs spawned by fish of ages III to IX in each region (Table 7) was calculated by subtracting the number of eggs retained in July from the number present in May. There was generally good agreement between the three regions in the number of eggs spawned by

Table 6. Mean Number of Eggs Retained in Ovaries of Female White Perch (ages 3 to 7 years) Collected in the Hudson River in July of 1972

Region	Number of specimens	Mean number of eggs retained	Confidence interval (95 per cent)
I	27	15,056	11,888 – 18,224
II	11	11,051	5,938 – 16,164
III	20	12,806	10,184 – 15,428

Table 7. Number of Eggs Spawned By Female White Perch Collected in the Hudson River in 1972

Region	Age (years)						
	3	4	5	6	7	8	9
I	22,831	40,403	52,415	61,693	81,826	78,466	135,289
II	30,052	49,305	55,044	70,387	83,699	174,309	..
III	20,676	36,118	52,602	71,062	95,516	72,752	114,314

fish of the same age. The differences noted for older fish were probably due to small sample size and variation in total length.

Fecundity estimates from this study were generally similar to those reported by Sheri and Power (1968). Taub (1969), however, found much higher values for fish of comparable ages, which are probably accounted for by the much longer body lengths he reported.

The uniform gradation of egg diameters observed in this study (0.10 to 0.71 millimeter) may account, in part, for the wide ranges in total length noted among young white perch collected during the following summer and fall. The data suggest that the eggs ripened gradually and that individual females may have spawned over a 2-week interval. Mansueti (1961) also reported that ovulation in white perch collected in the Patuxent Estuary is apparently spread over a period of a week or more.

Variations in individual growth rates of young and in actual spawning times of different adults also contributed to differences in total length among young white perch.

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ANALYSIS OF THE FIRST DEER HARVEST ON THE CARY ESTATE IN DUTCHESS COUNTY, NEW YORK[1]

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ABSTRACT

A controlled 16-day hunt for white-tailed deer was conducted on an 1,800-acre private estate to reduce an overpopulation estimated at 52 deer per square mile. Of the 243 individuals given permission to hunt, 90 had State-issued party permits that allowed the taking of a deer of either sex. Of all hunters, 26 per cent succeeded in bagging a deer. Of the 64 deer removed, which represented 40.8 per cent of the herd, 47 (73.4 per cent) were antlerless. Even though a maximum hunter density of one per 25 acres was encouraged, a median daily density of only one per 85 acres was achieved, a pressure too light for the herd reduction desired. The sex ratio (67.4 per cent females) among the adults taken was considered unbiased. The animals examined reflected poor nutrition, mainly in antler development. Data revealed that overpopulation on the area was probably due to the large proportion of relatively fertile adult does in the herd. Conversely, the age data indicated a high mortality rate among males, revealing that this 3-square-mile posted and patrolled property had not been a refuge for bucks. Factors believed contributing to the age and sex structures observed are discussed. Further hunting of antlerless deer is considered appropriate management to avoid further deterioration in wildlife habitat and the deer themselves.

From July 1969 to February 1972 the National Audubon Society was advisor on wildlife managament to the Trustees of the Cary Estate, an 1,800-acre private property located near Millbrook in the Town of Washington in Dutchess County, New York. Field studies soon revealed that, in winter at least, the population of deer (*Odocoileus virginianus*) on this property was well in excess of what its food supplies would support. Starvation and severe overbrowsing of vegetation were documented (Davis 1970, 1972a). A controlled harvest designed to reduce this population was deemed necessary to prevent further damage to wildlife habitat. The hunt was instituted during the regular open season for deer in the fall of 1970. Its results are reported here. The data presented also represent the first published documentation of deer/range relationships for the Eastern Slate Hills (Fenneman, 1938) of the Hudson Valley.

The Estate originated in 1929 when the Melbert Cary family of Millbrook purchased 13 parcels of rural land in the northcentral part of the Town of Washington. Their intention was to secure a large tract on

[1]The author wishes to thank Warren McKeon, Joseph Steeley and field technicians of the New York State Department of Environmental Conservation whose assistance helped make this undertaking possible as well as successful. John M. Anderson, Director of Sanctuaries of the National Audubon Society, played a key role in the project's success by expertly handling the sensitive public relations work needed to change the management traditions on the property involved.

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which to build a mansion. The home was never built, and some former landholders remained as tenant farmers until about 1954.

The Estate (also called Cannoo Hills) is situated in the Hudson Valley game range division of the State as described by Smith (1955). The property is ideal deer range consisting of varied topography and an excellent interspersion and diversity of cover types (Davis, 1972b). Prior to Cary ownership the area was composed of 12 farms with roughly half of the land cleared for pasture and crops. Abandonment of most of the farms occurred from the late 1930's through 1954. At the time of the work described here, the area comprised the following major cover types: agricultural land, 200 acres; oldfields, 500 acres; secondgrowth hardwoods, 500 acres; mixed softwoods and hardwoods, 500 acres; mature softwoods, 100 acres. Predominant tree and shrub species included: red oak (*Quercus rubra*), chestnut oak (*Quercus prinus*), white oak (*Quercus alba*), hickory (*Carya* spp.), sugar maple (*Acer saccharum*), red maple (*Acer rubrum*), black birch (*Betula lenta*), white pine (*Pinus strobus*), hemlock (*Tsuga canadensis*), red cedar (*Juniperus virginiana*), black locust (*Robinia pseudo-acacia*), apple (*Pyrus malus*), gray dogwood (*Cornus racemosa*), sumac (*Rhus* spp.) and shrub honeysuckle (*Lonicera* spp.). Dominant oldfield herbs included: goldenrod (*Solidago* spp.), little bluestem (*Andropogon scoparius*), sheep sorrel (*Rumex acetosella*) and cinquefoil (*Potentilla* spp.) in the uplands and purple loosestrife (*Lythrum salicaria*) in wet areas. The Estate contained numerous springs, seeps, small swamps and one main stream, the East Branch of Wappinger Creek. It was unfenced and adjoined prime deer range to the north and west. Commercialization and housing developments appeared to be semi-isolating the Estate from range of declining quality immediately south and east. The property, combined with several inholdings, represented about 3 square miles of deer range.

The recollections of Estate caretakers placed the first deer sighting, in recent time, around 1923. They reported these animals as very uncommon through 1938. They said deer became common during the 1940's and early 1950's, with considerable damage to shrubbery and other plantings beginning in the mid-1950's. These recollections correlate well with deer harvest data for Dutchess County as published by Severinghaus and Brown (1956). The Estate had always been posted. Intensive patrolling against deer hunters began in 1960 and continued for 10 years. During this time only a few deer were taken by legal hunting, although an unknown amount of illegal hunting occurred. It seems clear, however, that the total hunting pressure (legal and illegal) on deer in the north-central part of the Town of Washington had been light for at least 10-15 years prior to 1970. The attitude of most local landowners was well exemplified in local newspapers by quarter-page advertisements such as that in the Millbrook Round Table (in October 1970) which read "pro-

tect your land during the hunting season . . . order your posted signs now" and was accompanied by an illustration depicting a hunter shooting a deer.

OBJECTIVES AND CONDUCT OF HUNT

Based upon the degree of observed damage to vegetation (Figure 1) and the obviously large local deer population, the hunt's main objective

Figure 1. Overbrowsing (indicated by arrows) on red cedar (*Juniperus virginiana*) on the Cary Estate during the winter of 1969-70. Deer feed on red cedar only after they have exhausted the available supply of better-quality foods. Such overbrowsing was widespread on the Estate and adjacent areas.

was simply to obtain the maximum deer harvest possible while maintaining reasonable sport quality and safety standards. No kill quota was set since it was felt that overharvest was virtually impossible within the framework of a quality hunt and because of existing environmental conditions. Further, no reliable basis was available for setting such a quota.[3] The results and analysis of this first hunt were to be used to establish a deer harvest program compatible with a goal of range (vegetation) recovery. The ultimate deer population density to be sustained would depend upon area management objectives and commitments to habitat manipulation to be determined later.

[3]From a deer drive census on a 210-acre unit, a preseason population of 117 deer (about 39 per square mile) had been calculated for the property, which translated to 59 deer that would need to be taken to realize the hoped-for 50 per cent harvest. However, this estimate proved too low.

Another reason for the Audubon Society and the Estate's trustees to permit an open season hunt on the property was that it would afford recreational opportunity to local sportsmen in an area where the demand for hunting space exceeded the supply due to posting of private land. This approach, it was argued, would be more "sociologically responsible" than alternative means of reducing the deer population. Hence, a second objective was to promote controlled recreational hunting as a legitimate use of a renewable resource. It was felt that this concept of resource management needed a good demonstration in the locality.

The initial recommendation to the Estate's trustees was to place the property in the Dutchess County Cooperator Area and to manage the hunt under the provisions of New York's Fish and Wildlife Management Act. This arrangement was unacceptable to the trustees because they desired greater control over hunter selection than was possible under it. The second proposal was to allow hunting pursuant to the State's deer hunting party permit system, whereby, in Area W, individual hunters could be screened for special permits by certified landowners for their property. This was adopted as the mechanism for conducting the hunt.

A deer hunting party permit allows the party holding one to take, as a party, one deer of either sex in addition to the antlered deer which each member may take under his big game license. The special Area W permits were designed for use by landowners in parts of Columbia, Dutchess and Putnam Counties who were experiencing substantial crop damage. In 1970, two hunters were required to join in each application for such a permit.

A full quota of 90 party permits for the Estate were requested from the State Department of Environmental Conservation, and all were allotted. Hunter notification of available permits was accomplished by contacting three local fish and game clubs, but permit issuance was not limited to club members. Besides the 90 special party permits issued, complimentary permissions were also extended to selected individuals and groups. To be eligible to hunt on the Estate, all club members were required to obtain certification from their club president. Non-club hunters were confirmed by Audubon Society or Department personnel. In addition to these written endorsements, all hunters signed a liability release form prepared by the Estate's lawyers who were not convinced that State laws (particularly Article 9 of the General Obligations Law) afforded adequate landowner protection. Hunting was done during the regular open season in that part of the State (November 16-December 1) and was limited to the use of shotguns. All other provisions of the Conservation Law were in effect.

Field dispersal of hunters was achieved by establishing 22 evenly distributed parking areas on the tract and restricting parking to these areas. Parking was available on a first come-first served basis. Hunters finding

all parking areas occupied waited until space became available before taking to the field. To obtain an even distribution of hunters, parties were asked to hunt only on the same side of the road as their parked vehicle. Half of the parties were instructed not to begin hunting until the second week of the season, thus easing competition for parking on opening day and the first weekend. It was felt that these arrangements would yield a maximum of one hunter to about 25 acres.

To assure a sizable harvest of antlerless deer, all hunters carrying their party permit afield were told to shoot the first deer possible.[4] Party members not carrying the permit were allowed to take a buck under their big game license. Individuals successful in filling the permit were encouraged to also try for a buck on the Estate under their regular license. All deer taken were required to be examined at a State-operated checking station located at Verbank, 7 miles from the Estate. There, the animals were aged by Department technicians according to the tooth wear and replacement technique described by Severinghaus (1949). Antler measurements and weights were also recorded. Department personnel also assisted those of the Audubon Society in patrolling and checking hunters on the property throughout the season. Since armbands were not issued, identification of eligible hunters in the field was accomplished through name checks against an alphabetized list.

One month prior to the season, a letter along with two information leaflets (Seagears, 1954-55; Cheatum, undated) were sent to 13 neighboring landowners notifying them of the hunt and explaining the reasons for it. These 13 properties, ranging in size from 2 to 400 acres, were posted against deer hunting.

RESULTS

Records concerning the amount of hunting, the harvest achieved and its effect on the deer populations, together with data on the deer taken, are presented separately.

Hunting Pressure and Harvest

Of those who had permission to hunt on the Estate, 243 availed themselves of the privilege, of whom 90 carried the special Area W permit. This total also included those given complimentary permission, as well as holders of big game licenses and holders of regular party per-

[4] The regulations governing the party permit provided that the extra deer to which the party was entitled pursuant to it, whether antlerless or antlered, might be taken only by the party member carrying the permit at the time. Until it was filled, however, the permit might be carried by different members at different times.

mits[5] for Area W who were granted permission on days when the hunting pressure was light.

Hunters took 60 deer on the Estate during the 2-week season, with 20 being taken on opening day. Hence, assuming those few persons that did not hunt at all compensated for the few who killed two deer (a doe and a buck or two bucks), 24.7 per cent of all hunters were successful in bagging a deer. In addition, four deer that had been crippled were later found dead. Hunting pressure and the kill on each day are given in Table 1. Adverse weather conditions tended to discourage hunting on only two days, November 20 and 30.

The number of deer removed from the Estate probably exceeded the 64 animals recorded. There were undoubtedly a few crippling losses that went unaccounted for, and probably one or two deer were taken but not checked. Also, two deer were legally taken by other hunters within ⅛ mile of the Estate boundary. Thus, the total removed from the area and its immediate vicinity was likely about 70 animals.

Table 1 reveals that the well-known pattern of heavy opening-day pressure and kill, with similar levels on the first weekend, characterized this hunt. Typically also, the kill dropped off later in the season despite relatively heavy pressure on Thanksgiving and the second weekend. Hunting from stands and still hunting (stalking) were the chief methods used. It is noteworthy that heavy gunning pressure occurred on only five days of the 16-day season. This demonstrates the difficulty in generating the sustained heavy pressure needed for drastic herd reduction, even where excellent access and a high (but controlled) hunter population exist. Based on a deer population estimate of 157 as calculated from the harvest data and natural mortality records, 40.8 per cent of the Estate's presumed preseason herd was removed.

Including those crippled and later found dead[6], 49 antlerless deer were harvested by the 90 special party permit holders, while the 243 potential buck hunters were able to take only 14 antlered deer. Thus, if the hunt had been restricted to antlered bucks only, a regulation favored by some hunters, only 8.9 per cent of the herd would have been removed. These data show the necessity of a sizable harvest of antlerless deer where the reduction of an overpopulation is desired.

As noted earlier, limited hunting space (i.e., parking) was available to permitees on a first come-first served basis. Observations indicated

[5] In addition to the special party permits issued in collaboration with certified landowners for abating deer damage problems on their property, regular party permits were also issued for Area W generally in the same way as in other parts of the State.

[6] Of the four deer that were crippled and later found dead, and that are included in Table 1, one was not aged or sexed so that further data for it are lacking.

Table 1. Deer Taken and Hunting Pressure During Hunt on Cary Estate in 1970

Date	Deer taken	Hunting pressure		
		Number of hunters*	Hunter density§	Density index
November 16	20	75	24	heavy
17	4	40	45	heavy
18	5	35	51	moderate
19	1	10	180	low
20	1	10	180	low
21 (Saturday)	8	45	40	heavy
22 (Sunday)	8	45	40	heavy
23	3	16	113	low
24	0	10	180	low
25	1	10	180	low
26 (Thanksgiving)	4	50	36	heavy
27	1	12	150	low
28 (Saturday)	1	25	72	moderate
29 (Sunday)	1	18	100	moderate
30	1	5	360	low
December 1	0	8	225	low
Unknown	1	..	..	..
Total bagged †	60	..	..	..
Crippled and later found dead	4	..	..	..
Total removed	64	..	..	..

* Estimated from car counts (assuming two hunters per car) plus other individuals hunting by special arrangement and suspected trespassers.

§ Acres per hunter (approximate).

† Deer taken home by hunter.

that on only four days (opening day, the first Saturday and Sunday, and Thanksgiving) were some hunters inconvenienced by an inability to secure parking for early-morning hunting. On three of these days, parking became available by about 10 a.m. as early-morning hunts were completed. Only on opening day did contention among hunters for parking space present a problem serious enough to warrant an adjustment of regulations in any subsequent hunt of this sort.

Of concern in this hunt was the conduct of hunters and the reactions of bordering landowners unaccustomed to intensive shooting levels. Problems associated with hunter misconduct were minimal. Several parking violations occurred; one hunter's permission was revoked. A specific complaint was received from only one neighbor—a trespass complaint on opening day. Littering amounted to a half bushel of material. Perhaps the most serious infraction (suspected) was the sneaking onto the property of individuals who did not have permission. Considering that 243 persons had permission to hunt, this low number of incidents reflects admirably on the local hunting community. Most people took their deer hunting seriously and seemed appreciative of the hunting opportunity. There were no accidents.

Table 2. Age Distribution, By Sex, of Deer Taken During Hunt on Cary Estate in 1970*

Age (years)	Male		Female		Total	
	Number	Per cent	Number	Per cent	Number	Per cent
1½	8	57.2	9	31.1	17	39.5
2½	2	14.3	4	13.8	6	13.9
3½	3	21.4	8	27.6	11	25.6
4½	0	..	2	6.9	2	4.7
5½	1	7.1	1	3.4	2	4.7
6½	0	..	3	10.4	3	7.0
7½	0	..	1	3.4	1	2.3
8½	0	..	1	3.4	1	2.3
Subtotal (adults)	14	100.0	29	100.0	43	100.0
½ (fawns)§	12	..	8	..	20	..
Total	26	..	37	..	63	..

* Includes three (a yearling male, a fawn male and an 8½-year-old female) of the four deer that were crippled and later found dead; these data were not recorded for the other.

§ Of all age groups, fawns are the most likely to have been underrepresented, because of some hunter reluctance to shoot small deer.

Age Structure of Deer Population

Data on age structure are valuable in interpreting the dynamics of game populations and can often be obtained through hunter bag checks. For deer, they can reveal age-related mortality rates over a period of some 10 or more years prior to the harvest. By correlating these rates with knowledge of range conditions, weather patterns, harvest systems and other environmental influences, biologists can gain the insights needed for sound deer management.

The conclusions drawn from age data depend upon the assumptions that the investigator is willing to make about the representativeness of his sample. In the present analysis, the assumptions made were: (1) that deer were shot at random with respect to age, thereby yielding a sample representative of the population as a whole; and (2) that the population being dealt with was "stationary" (i.e., neither increasing nor decreasing significantly in size), so that age-related mortality and fertility rates remained more-or-less constant during the time period covered by the sample. The validity of the first assumption is supported by the work of Maguire and Severinghaus (1954). Eberhardt (1969) discussed the complexities of a stationary population and pointed out that "The population in one year is almost always closely correlated with that of the year before. There may often be an approach to the stable age distribution . . ."

The age distribution by sex of the deer taken on the Cary Estate in 1970 is shown in Table 2. Of the 14 adult males, only one was over 4½ years old, suggesting that in the population as a whole there were

likewise very few old males. In contrast, the age range for females was noticeably greater with 27.6 per cent of the sample being 4½ years old or older. Such differences in longevity between sexes are typical of herds in heavily hunted areas where, even though both sexes may be taken, sportsmen tend to select bucks for their trophy value, taking does at a much lower rate (C. W. Severinghaus, personal communication, 1970). However, accepting this as the sole explanation for these statistics is unsatisfactory since the Estate had been virtually unhunted for at least a decade. The data for males also disproved the popular notion among local hunters that this long-unhunted property served as a refuge where numerous bucks grew old and, hence, into trophy specimens. Possible causes for the high attrition among males are discussed later.

In Figure 2 the age distribution is portrayed graphically and compared with an age pyramid showing the "normal" structure of a roe deer population. Age pyramids reveal the proportionate sizes of age groups within a population. They illustrate a basic tenet of population dynamics which states that within a given cohort some animals will die in a year's time so that there will be fewer members alive with each succeeding year. Hence, assuming an equal number of births annually and a relatively constant mortality, a random sample of a population in the fall would consist of fewer 2½ year olds than 1½ year olds, fewer 3½ year olds than 2½ year olds, and so on. The roe deer approached this pattern, whereas the white-tails on the Cary Estate departed from it. In particular, the number of 2½ year olds was small in proportion to the 3½ year olds. This shortage of 2½ year olds may have been a result of the decimation of this cohort as fawns during the unusually severe winter of 1968 when near-record snowfalls occurred in Dutchess County as noted by Flanagan (1969). The fact that the difference was greatest among females supports this explanation since female fawns, which average smaller than male fawns, are usually less successful than their brothers in procuring food in deep snow. The unevenness, or notched pyramid, and the disproportionate absence of older males among the deer on the Cary Estate suggest a "stressed" population.

Sex Structure of Deer Population

On the average, white-tailed deer give birth to more males than females. This results in an unbalanced sex ratio among fawns in the fall, with 51.5 per cent being males (Severinghaus and Cheatum, 1956). However, as the cohort ages, this ratio generally shifts in favor of the females due to much higher exploitation of the males. Mortality among the males may also be greater due to behavioral differences between the sexes.

The sex distribution of the deer taken on the Cary Estate is also given in Table 2. Among the adults, the sample was comprised of 14 males (32.6 per cent) and 29 females (67.4 per cent). Predictably, the sex

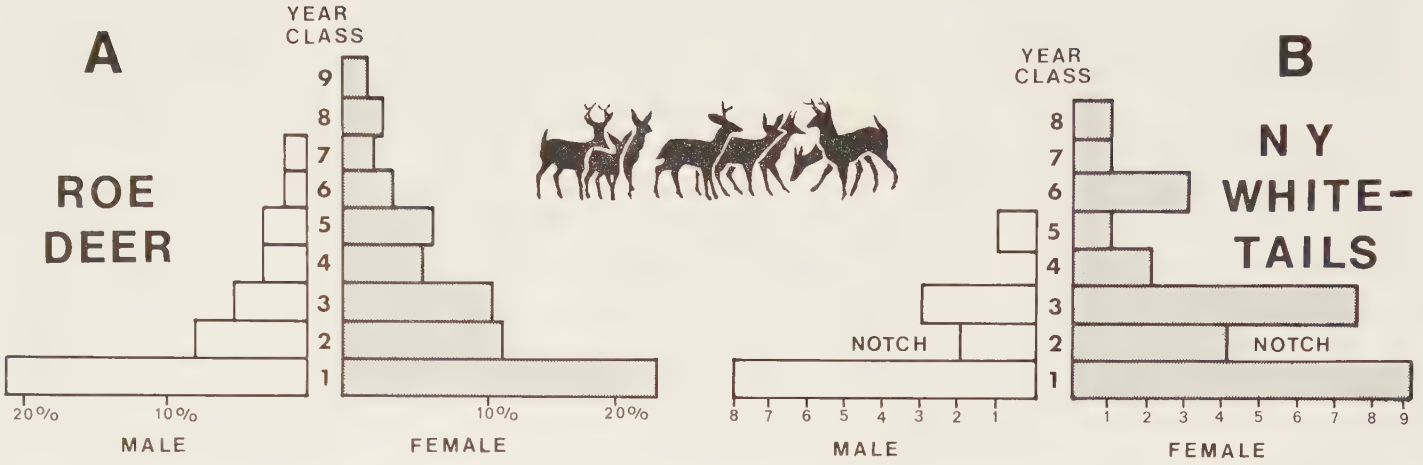

Figure 2. Age structure of the deer population on the Cary Estate in 1970 compared with that of a roe deer population as given by Quick (1963).

ratio among the fawns favored males (12 to 8) but was less unbalanced than that of the adults. With respect to the population as a whole, it is reasonable to postulate that the composition of the fawn kill was more nearly representative of the population parameter than was the adult sample. Because hunters have no way of distinguishing the sex of fawns, and presuming both sexes were equally vulnerable to the gun, this sample should have been unbiased. The sex of adults, on the other hand, is readily distinguishable. And, because the hunt design and prevailing hunter mores tended to generate more pressure on males, it might be expected that proportionately more bucks than does would have been killed than existed in the population. Using the method developed by Severinghaus and Maguire (1955), an adult population consisting of 1.74 females per male (i.e., 63.4 per cent females) was calculated. Thus, based on a comparison between the sex ratio derived in this way and that calculated from the raw data (i.e., 67.4 per cent females), bucks were apparently not harvested disproportionately.

Physical Characteristics of the Deer

The major deer management problem in Dutchess County (N.Y.), as well as in many other localities in the Northeast, often centers around balancing deer numbers with the available food supply. Whether or not deer nutrition is adequate can best be determined by examining certain physical attributes of the animals. Accordingly, biologists have collected and analyzed such measurements as weight, antler size and hind foot length. Data on weight and antler development for deer taken on the Cary Estate may be compared with similar information for populations on ranges having from very poor to very good forage conditions.

The field-dressed weights of deer from the Cary Estate are given in Table 3, and those for deer from other areas are given in Table 4. For perspective, the data for Ohio probably represent the normal growth pattern of the northern white-tailed deer (*O. v. borealis*) where food is abundant and nutritious at all seasons. The mean weights of both fawns and adults from the more eastern states appear significantly lower and may reflect a lower nutritional plane. Weights of fawns from the Cary Estate were good compared with those from northern and western New York, New Hampshire and Pennsylvania. However, fawn weights may fluctuate noticeably depending on the annual scarcity or abundance of fall mast crops (White, 1968). Also, fawn size only reflects the quality of the food on their summer and fall range. These animals have yet to experience a winter season when their food supply may be sharply limited. Weights of yearlings and adults from the Cary Estate compared favorably with those from the other northeastern areas, but judging from the Ohio data the Estate's yearlings fell short of their growth potential.

Antler beam diameter and the degree of branching are also sensitive

Table 3. Field-dressed Wieghts, By Age and Sex, of Deer Taken During Hunt of Cary Estate in 1970

Age and sex	Number*	Weight (pounds)			
		Mean	Standard deviation	Maximum	Minimum
½ year					
Male	10	65.1	6.03	74	60
Female	7	60.7	8.36	67	49
1½ years					
Male	6	113.8	9.51	130	98
Female	7	94.1	7.02	106	80
2½ years					
Male	1	142.0	..	..	..
Female	3	113.6	13.00	132	104
3½ years					
Male	3	154.6	17.40	178	136
Female	8	112.2	6.43	123	103
4½ years					
Male	0	..	..	..	..
Female	2	112.5	§	118	107
5½ years					
Male	1	178.0	..	..	..
Female	1	110.0	..	..	..
6½ years					
Male	0	..	..	..	..
Female	0	..	..	..	..
7½ years					
Male	0	..	..	..	..
Female	1	122.0	..	..	..

* Due to the number of deer passing through the checking station at certain times, not all of them were weighed.

§ Not calculated.

indicators of range quality (Cowan and Long, 1962; Severinghaus et al., 1950). Antler measurements for deer from the Cary Estate are given in Table 5, and they are compared with those from two major deer research areas in upstate New York in Table 6. On the Seneca Army Depot in Seneca County where the deer range had become very much deteriorated by 1957, the data show that by 1961 antler growth had improved as a result of harvest management. On the other hand, on the Moose River Recreation Area in Hamilton County, where the range was poor in 1964, the data reflect worsened conditions in 1967. It is evident from these data that the animals on the Cary Estate were undernourished with regard to antler growth.

It is known that on an optimum diet many yearling bucks will grow antlers having six to eight points (Severinghaus and Cheatum, 1956). Of

Table 4. Field-dressed Weights, By Age and Sex, of Deer Taken During Hunt on Cary Estate in 1970 Compared With Those of Deer Taken During the Fall in Other Localities*

Locality	Forage	Fawn		1½ years and older		Yearlings only	
		Male	Female	Male	Female	Male	Female
Cary Estate	Inadequate	65.1 (10)	60.7 (7)	133.4 (11)	107.0 (22)	113.8 (6)	94.1 (7)
Central Adirondacks (N.Y.)§	Poor	53.6 (173)	51.3 (173)	114.4 (440)	90.0 (658)	83.6 (166)	79.2 (144)
Southern Tier (N.Y.)§	Adequate	64.9 (71)	57.7 (76)	125.5 (62)	103.4 (149)	..	..
Northern New Hampshire†	Adequate	64.0 (9)	56.2 (9)	..	..	107.2 (63)	96.1 (50)
Pennsylvania‡	Inadequate	..	..	119.6 (195)	93.0 (59)	..	..
Ohio‡‡	Very good	75.7 (98)	70.9 (83)	161.4 (45)	115.9 (46)	129.2 (51)	104.0 (47)

* Figures in parentheses represent number of deer.

§ From Severinghous (1955).

† From White (1968).

‡ From Donaldson and Doutt (1965).

‡‡ From Nixon et al. (1970).

TABLE 5. ANTLER DEVELOPMENT OF MALE DEER TAKEN DURING HUNT ON CARY ESTATE IN 1970

Age (years)	Beam diameter			Number of points		
	Number of deer	Mean*	Range*	Number of deer	Mean	Range
1½	7	16.3	13-18	8	2.6	2-6
2½	2	18.0	17-19	2	4.0	3-5
3½	3	25.0	23-28	3	7.7	7-8
4½	0	..	..	0	..	..
5½	1	33.0	..	1	9.0	..

* Millimeters.

TABLE 6. ANTLER DEVELOPMENT (EXPRESSED AS AVERAGE) OF MALE DEER TAKEN DURING HUNT ON CARY ESTATE IN 1970 COMPARED WITH THAT OF DEER TAKEN IN OTHER LOCATIONS IN NEW YORK*

Locality	Age (years)		
	1½	2½	3½
Beam diameter (millimeters)			
Cary Estate	16.3 (7)	18.0 (2)	25.0 (3)
Seneca Army Depot §			
1957	16.2 (?)	23.0 (?)	29.5 (?)
1961	18.2 (?)	24.3 (?)	29.0 (?)
Moose River Recreation Area †			
1964	15.5 (20)	24.2 (16)	27.0 (4)
1967	14.1 (34)	20.9 (52)	25.4 (35)
Number of points			
Cary Estate	2.6 (8)	4.0 (2)	7.7 (3)
Seneca Army Depot §			
1957	3.4 (?)	6.5 (?)	8.2 (?)
1961	4.2 (?)	8.0 (?)	9.2 (?)
Moose River Recreation Area †			
1964	2.8 (20)	6.9 (16)	7.5 (4)
1967	2.4 (34)	5.2 (52)	7.3 (35)

* Figures in parentheses represent number of deer.

§ From Hesselton et al. (1965).

† From Dickinson and Severinghaus (1969).

the eight yearlings in the Cary Estate sample, only one had six points, one had three points, and six had two point ("spike horns"). Spikes are the classic sign of a diet incapable of supporting normal antler development. Again, the data (Tables 5 and 6) reveal that, in the Estate sample, the antlers were typical of deer living on ranges depleted of good winter browse.

Apparently, habitat conditions on the Cary Estate had not yet deteriorated to the level existing in some other deer concentration areas

(e.g., the central Adirondacks). Weightwise, these deer compared well with those from the southern tier counties of New York where food was judged to be "good". No sublegal antlers (less than 3 inches long) were observed on 1½- or 2½-year-old males as have been found in the Adirondacks according to Dickinson and Severinghaus (1969) and Severinghaus and Cheatum (1956). Physiologically, deer utilize available nutrients first for body growth and maintenance. "Surplus" nutrients may then be channeled into antler production. Thus, it seems that the population on the Cary Estate showed, in antler characteristics, the initial effects of lowered nutrition, but advanced malnutrition as evidenced by stunted body growth had not yet developed to a serious degree. It is relevant to note that the deer/food balance problem is being considered here in terms of deer growth and vigor, rather than in terms of the effect on range vegetation which showed advanced deterioration on the Estate.

Deer Population Before and After Hunt

Three procedures were used for estimating the deer population prior to the hunt. These involve: (1) a deer drive census made on May 3, 1970 (Davis, 1970), which gives a conservative estimate; (2) harvest data collected during the hunt, from which a minimum population estimate can be calculated (Severinghaus, 1969); and (3) harvest data plus natural mortality records, from which a more realistic estimate can be derived (Free et al., undated). Population estimates calculated by these three methods are given in Table 7. Of course, apart from natality and mortality, the population on the Estate was not static. Deer numbers on the property continually fluctuated as animals moved back and forth across the unfenced boundaries. It is more appropriate to think of an "average" population.

Concerning the equation developed by Free et al. (undated), it should be noted that, in contrast to the other two methods, it undoubtedly yielded an overestimate of the Estate's population. In this method,

Table 7. Deer Population on the Cary Estate in the Fall of 1970 Prior to the Hunting Season According to Different Estimates

Estimate	Number of deer				Deer per square mile	Acres per deer
	Adult					
	Male	Female	Fawn	Total		
Drive census	41	31	45	117	39.0	16.4
Minimum*	46	26	58	130	43.3	14.7
Realistic§	64	37	81	182	60.7	10.6
Realistic†	54	31	72	157	52.3	12.1

* After Severinghaus (1969).

§ After Free et al. (undated).

† After Free et al. (undated), but modified as explained in text.

natural mortality records (adult males lost from starvation, accidents, etc.) are included along with harvest records as basic input into the equation. The bulk of the natural mortality on the Estate comprised deer that died during the winter. But, because the Estate was apparently a wintering area for many deer from the surrounding range (Davis, 1972a), it was impossible to distinguish between carcasses of resident deer and those of animals that would have departed the property once the snow had melted. Therefore, a probably disproportionately large number (i.e., seven) was entered into step 1 of that equation to represent adult males lost from causes other than legal hunting. For this reason, the calculation was arbitrarily modified by using three instead of seven as more nearly representing the number of resident adult males lost in this way. The results, also shown in Table 7, gave a total population of 157 deer.

The deer population following the hunt was estimated at about 90. By applying age-related fertility rates (data courtesy of W. T. Hesselton, State Department of Environmental Conservation, 1970) to the remaining females, a maximum fawn production was computed. Addition of these new animals to the residual adults yielded an estimated population of 135 deer for the fall of 1971.

DISCUSSION

Although the desired herd reduction on the Cary Estate was not achieved, the hunt produced valuable information concerning the management of deer populations on areas of this sort.

Hunting Pressure and Harvest

It is of interest to compare the results of this hunt with those from other controlled-hunting systems reported in the literature. In a hunt on the Huntington Forest in the Adirondacks in 1966, where hunter densities were fairly similar, a kill of 15 deer per square mile (compared with 20 per square mile in this hunt) was achieved (Behrend et al., 1970). Although that was a lower rate of harvest, it was distributed over a larger area (5,200 acres) and resulted in a total kill twice that on the Cary Estate. However, on the basis of deer killed per number of permits issued, the hunter success rate was about four times greater at the Estate, reflecting the higher deer population density there. The most important difference between the two hunts was in proportionate herd reduction. The Adirondack hunt took 56 per cent of the preseason herd, whereas at the Cary Estate an estimated 41 per cent were harvested. The latter figure was about equal to the annual increment, and it appears that the kill needed for the desired herd reduction was not achieved. The greater success of the Adirondack hunt may have been due to the fact that high hunter densities were sustained over a longer period. Another

problem on the Cary Estate, which was related to its relatively small size, was that, following heavy early-season hunting, harassed deer may have dispersed off the property making them unavailable to most hunters.

A controlled deer hunt on a 14,000-acre refuge in Illinois, designed to remove 50 per cent of the deer from a herd of 100 per square mile, was successful in taking approximately 47 per cent (Roseberry et al., 1969). That operation succeeded in sustaining a hunter density of nearly one per 30 acres throughout a 10-day hunt. Success was apparently achieved through a high degree of hunter regimentation and staff supervision involving 3,232 hunters and 22 employees.

These experiences reveal the management sophistication needed to successfully manipulate deer population densities in a controlled and orderly fashion on limited areas while concurrently incorporating important sociological and outdoor values in the over-all plan.

Population Dynamics and Management

The presence of few deer over 4½ years old in a population indicates heavy mortality (Dickinson and Severinghaus, 1969; Nixon, 1956). What contributed to such mortality among bucks on the Cary Estate, which had supposedly been a 3-square-mile refuge, cannot be answered with certainty. However, some speculations are offered as food for thought.

Information on home-range size of deer according to age and sex is apparently meager. From the few accounts available (e.g., Severinghaus and Cheatum, 1956), it would appear that 3 square miles would be sufficiently large to contain the movement of most resident deer. However, for males on the Cary Estate, the age data indicate that this was not the case. Male deer at times travel quite widely, for instance yearlings during the fall rut. Such movement, as well as that related to procuring food on depleted range, may have taken males into areas surrounding the Estate where they became exposed to hazards such as automobile traffic, relatively heavy buck hunting (in November during the peak of the rut), high numbers of dogs and poaching. Ohio data (Nixon, 1965) show disproportionately more bucks than does killed by automobiles annually, particularly in the fall. Deer have been killed illegally on the Estate, but no evidence that poaching was intense or selective toward bucks was found. Apparently, the Cary Estate, locally presumed to be an 1,800-acre "deer sanctuary" in central Dutchesss County, afforded little sustained protection to adult male white-tails in the 1960's.

Although the population estimates in Table 7 have shortcomings, they are accurate enough, together with the data on physical attributes, to constitute solid evidence that deer population densities were excessive in terms of the available food. A low fertility rate, that can be extrapolated to the Estate, was observed in fawn and yearling does on an adjacent area (Hesselton and Sauer, 1973). Starvation was documented at the

Estate (Davis, 1970). Considering these factors, one might wonder why the population in and around the Estate had remained high. The explanation seems to lie in the large proportion of older, more fertile does in the herd. The accumulation of does 2½ years old and older apparently resulted from the reluctance of local hunters to shoot females in adjacent areas over the years. The ranks of this productive segment of the female population were kept supplied by the recruitment of female fawns, especially following periodic mild winters. The resultant abundance of does in surrounding areas could have contributed to and/or sustained a high resident population on the Estate through ingress. If this was true, then the age-sex structure of the Estate's herd may have approximated that in the township as a whole.

Continuing management on the Cary Estate may be complicated by having to deal with two populations of deer—a resident population (deer that stay in and around the property throughout the year) and a larger wintering population which presumably includes deer that are present only during this season. Based on systematic roadside counts (Davis, 1972a), the immigrating animals may swell the population by two to three times. Thus, even if efforts to reduce the resident herd by open-season hunting were successful, winter range problems may remain. If, as it appears, the Cary Estate is only a portion of a wintering range extending throughout the northwestern quarter of the Town of Washington, then real success in balancing the deer population and its food supply will hinge on lowering the larger basic herd and not just some portion of it.

Reduction of populations that have outstripped their food resources is not the sole objective of deer management. Professional wildlife managers are concerned with a much broader problem which includes sustaining healthy deer populations as part of the natural fabric of rural landscapes, thereby contributing an enriching element to man's standard of living. This high goal can only be achieved through fundamental changes in how Americans think about and use the land, its soil, vegetation and animal life. Deer herd reduction is only a necessary first step on the difficult road back to a more balanced rural ecosystem in the Eastern Slate Hills.

Management Sequel

Impending changes in organizational control at the Cary Estate ruled out any deer hunting in 1971. Since then, under the auspices of the New York Botanical Garden, two controlled open-season hunts have been held. In 1972, twelve bucks were taken, and in 1973, again within a party-permit framework, a total of 56 deer were harvested (Robert Tillman, personal communication, 1974). Dr. Tillman reported that deer were still "numerous" in and around the Estate (now the Cary Arboretum

of the New York Botanical Garden) but that, due to three successive mild winters, the browse line on red cedar had partially disappeared as the animals had been little restricted in their pursuit of more preferred winter foods. Deciduous shrubs and hardwood reproduction still showed signs of heavy browsing.

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FISH BEHAVIOR AS REVEALED THROUGH STOMACH CONTENT ANALYSIS[1]

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ABSTRACT

Analysis of stomach contents of fishes not only reveals what prey organisms are taken, but it also reveals many aspects of the ecology and habits of the predator such as vertical and horizontal movements, day/night activity, competition between species and degree of adaptability to changes in food abundance and types. Such studies may also be useful in describing the biotic environment in which the fish live, e.g., the seasonal, temporal and spacial abundance of prey organisms. Energy-flow through an ecosystem can be visualized by understanding the type of feeders present and their trophic levels. To illustrate the use of fish stomach analysis in understanding fish behavior data are given for the windowpane flounder (*Scophthalmus aquosus*) in Long Island (N.Y.) waters.

The objectives of dietary studies of aquatic animals are to understand how these animals live and grow, what foods may influence their abundance and distribution, and the relative quality of feeding conditions. Feeding is usually the dominant activity of an animal's life because of its constant need and the scarcity of available food (Royce, 1972).

Dietary studies of fishes enable the ichthyologist to understand some of the relationships between species (Bayliff, 1950) and to determine the over-all availability of food present in the environment (Mulkana, 1966). Benthic and planktonic studies of indigenous organisms are useful in determining community structure, but they can in no way demonstrate what will be eaten by community members. Stomach content analyses of fishes often reveal organisms to have been ingested which have not been collected by conventional benthic sampling gear. Organisms common to both the benthos and the fish's diet are often encountered in far greater numbers in stomachs than would be expected by inspection of benthic standing crop values. Analyses of forage-organism types aid the observer in estimating vertical and horizontal migrations of the predator, as well as seasonal changes in the availability of food sources. Competition between species can be more clearly understood by inspection of the similarities and differences of dietary items. Day/night activity may also be revealed by the degree of observed satiation of fish stomachs (Austin, 1971). Readily changeable food habits indicate a high degree of adaptability to changes in the abundance of food (Royce, 1972), which may, in turn, be indicative of environmental changes.

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Fish species which are of no commercial importance in themselves may be of indirect economic value due to the degree to which commercially valuable species depend on them as food sources. Such information enables commercial enterprises to determine where and when to expect good harvests, as well as which baits may produce the best catches. Aquacultural interests may also profit from knowing what food sources are most acceptable and most desirable for a culture species.

Energy-flow through an ecosystem can be visualized by understanding the types of feeders present and their trophic levels. Royce (1972) described four aquatic trophic levels as follows:

1. producer level (plants)
2. herbivore level
3. first carnivore level (carnivores that eat herbivores)
4. second carnivore level (higher carnivores)

Regier and Henderson (1973) noted that it is often difficult to place a particular fish species in any one level due to:

1. seasonal changes in food abundance
2. the ability of many species to accept a wide variety of food types
3. changing requirements and preferences during the development of a fish

To illustrate the use of stomach analysis in understanding fish behavior, the feeding activities of the windowpane flounder (*Scophthalmus aquosus*) in the vicinity of Northport (N.Y.) may be used.

METHODS

Specimens were captured by using a 30-foot head rope semi-balloon otter trawl in the area fronting the Long Island Lighting Company's power station at Northport. Collections were made at two sampling stations once each month during April, June, July, August, October and December in 1972. One was an inshore station with a mean low water depth of 10 feet or less, and sampling was done perpendicular to the shoreline. The other station was farther offshore, and sampling was done along the 40-foot (mean low water) isobath. These locations are shown in Figure 1. Sampling was carried on during mid-morning hours. A subsample of fish representative of the size range of the catch as a whole was kept from each station and preserved in formalin immediately upon capture. The inshore station yielded sufficient numbers of fish to allow accurate representation of their stomach contents only during April, October and December. At the offshore station, sufficient numbers were captured during all months sampled except July.

Coincident seining was done on the beach opposite the inshore station, as described by Austin et al. (1973). Benthic sampling was also under-

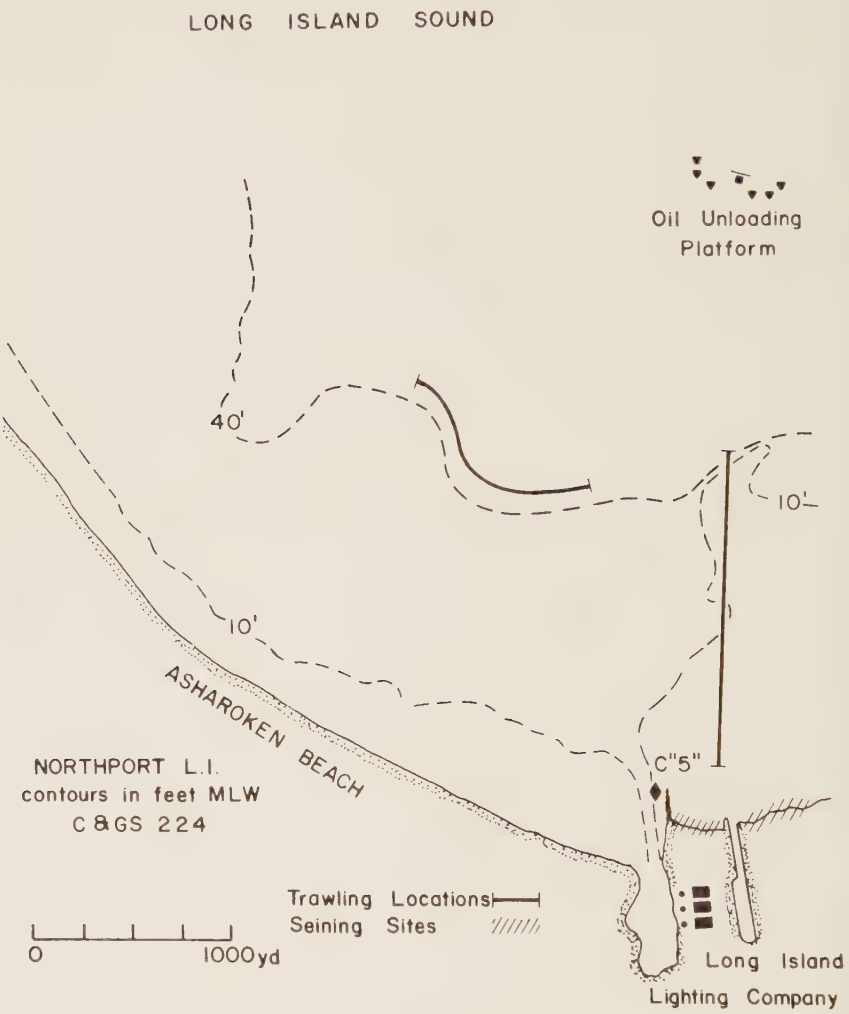

Figure 1. Trawl and seine sampling locations at Northport, New York.

taken in the area as a separate study (D'Agostino and Colgate, 1973). When ichthyofaunal and benthic sampling periods coincided, comparisons could be made between the food items ingested and their abundance and distribution in the Northport area.

In the laboratory, the stomachs were removed intact by severing at the esophagus and pyloric constriction. They were then cut open and the contents sorted, and the relative volume of each item was estimated in a manner similar to that of June and Carlson (1971).

RESULTS AND DISCUSSION

A total of 120 stomachs of *S. aquosus* were obtained for examination. The major prey organism at both sampling stations was consistently the mysid shrimp *Neomysis americana*. This food source never amounted to less than 35 per cent by volume, and in all months but one (August) it amounted to more than 55 per cent (Table 1). Moore (1947), Bigelow and Schroeder (1953), deSylva et al. (1962), Richards (1963) and Amish (1972) have reported that *N. americana* is a major prey of this fish. Secondary, yet important, food items were fish and the sand shrimp (*Crangon septemspinosa*). Inclusion of *Crangon* is in agreement with all of the foregoing authors except Amish (1972). Only at the offshore station in August was *Neomysis* not the predominant food item, being exceeded by *Crangon*. Similarly, Moore (1947) reported that *Neomysis* was exceeded only once, also by *Crangon*.

Previous authors have all suggested that fish are only of minor importance in the diet of *S. aquosus*, and fish were not reported to occur at all by Richards (1963). The present study, however, indicates that fish are an important dietary item of this species in the Northport area, having been eaten at both stations in every month (of those sampled) except April. This may reflect an absence of small prey species at that time. Anchovies (*Anchoa mitchilli*) were captured by trawling only in August and October, and coincident beach seining took them only in October. As anchovies (*Anchoa* sp.) were eaten at both sampling stations only in October, their inclusion in the diet of *S. aquosus* appears to relate to their seasonal abundance. Similarly, Atlantic silversides (*Menidia menidia*) were eaten only in August at the offshore station, when they were also at their peak of yearly abundance.

Molluscs (bivalves) were eaten only by offshore fish and only during April, June and October. Collections of benthic organisms by D'Agostino and Colgate (1973) showed that bivalves ranked first in abundance during June and October in the offshore area. Polychaetes were eaten only by inshore fish and only in December. Benthic sampling was not carried on in December of 1972, but the benthos were sampled in December of 1971 and polychaetes ranked first in abundance in the inshore area at that time. It appears, then, that the inclusion of these items in the diet of *S. aquosus* relates to their seasonal abundance and thus to their availability as food.

At both sampling stations, the food preferences of *S. aquosus* differed with size and age. Small inshore fish (0+ or young of the year) during October and December ate almost exclusively small crustaceans (copepods and *Neomysis*), while larger fish (2+ to 4+ years old) ate small crustaceans, fish and decapods (Figure 2). Likewise, small offshore fish (0+) from June to December ate primarily small crustaceans, while larger fish (0+ to 4+) ate small crustaceans, fish and decopods. Larger

TABLE 1. STOMACH CONTENTS OF WINDOWPANE FLOUNDERS COLLECTED IN THE VICINITY OF NORTHPORT, NEW YORK, IN 1972*

Food item	Inshore stations§						Offshore stations§									
	April		October		December		April		June		August		October		December	
	Frequency	Volume	Frequency	Volume	Frequency	Volume	Frequency	Volume	Frequency	Volume	Frequency	Volume	Frequency	Volume	Frequency	Volume
INVERTEBRATES																
Mollusca																
Bivalvia	..	..	..	..	..	..	72.7	6.0	64.7	4.0	..	..	5.3	0.3	..	..
Annelida																
Polychaeta	..	..	..	..	4.3	0.9	..	..	..	..	..	..	..	..	..	..
Arthropoda																
Larvae	..	..	..	..	..	..	..	..	..	..	..	..	5.3	5.3	..	..
Copepoda	..	..	33.3	4.4	34.8	1.3	..	..	..	..	..	..	5.3	0.3	47.4	2.2
Amphipoda	22.2	1.7	..	..	..	..	9.1	0.1	..	..	..	..	..	..	10.5	2.9
Mysidacea																
Neomysis americana	100.0	78.3	100.0	77.8	87.0	70.5	100.0	88.6	100.0	79.5	50.0	35.0	89.5	55.8	100.0	89.7
Decapoda																
Caridea																
Crangon septemspinosa	33.3	20.0	..	..	13.0	3.7	36.4	4.2	11.8	3.5	87.5	53.8	26.3	7.6	..	..
Paguridae																
Pagurus spp.	..	..	..	..	..	..	18.2	1.1	..	..	..	..	..	..	..	..
VERTEBRATES																
Pisces																
Fish eggs	..	..	..	..	..	..	..	..	..	..	12.5	1.3	..	..	..	..
Fish larvae	..	..	11.1	0.1	..	..	..	..	..	..	..	..	..	..	..	..
Menidia menidia	..	..	..	..	..	..	..	..	..	..	12.5	10.0	..	..	..	..
Anchoa spp.	..	..	11.1	11.0	..	..	..	..	..	..	..	..	15.8	7.9	..	..
Brevoortia tyrannus	..	..	..	..	13.0	10.6	..	..	..	..	..	..	..	..	5.3	5.2
Unidentified fish	..	..	11.1	6.7	17.4	12.2	..	..	29.4	12.2	..	..	47.4	22.9	..	..
MISCELLANEOUS																
Digested material	..	..	..	..	4.3	0.9	..	..	17.6	0.7	..	..	..	..	..	..
Number examined	11		11		23		12		17		8		19		19	
Number empty	2		2		0		1		0		0		0		0	
Size range (millimeters)	170–255		68–264		72–222		150–247		82–215		117–206		58–189		66–178	

* For each month, figures for frequency and volume represent, for each food item present, percentage of full stomachs containing the item and percentage of total volume of food in those stomachs, respectively.

§ See text for definition.

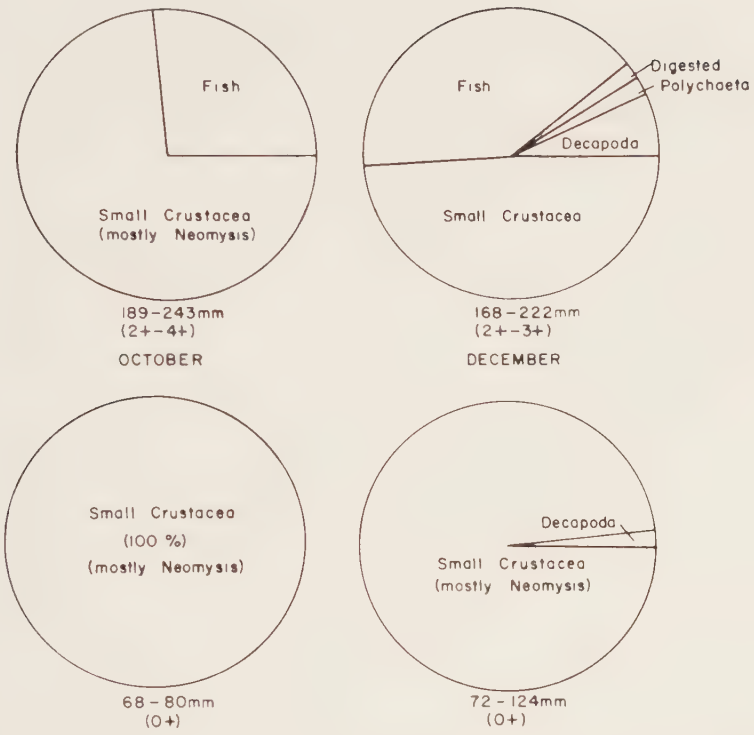

Figure 2. Stomach contents in relation to fish size for windowpane flounders taken by trawling inshore at Northport (N.Y.) during different months. Diagrams represent percentage by volume.

offshore fish showed an increasing acceptance of fish in their diet from June through December (Figure 3). Because the larger fish accepted larger prey organisms, their competition with smaller fish was reduced, thus giving young fish a greater chance for survival as noted by Keast (1974).

In the Northport area in 1972, then, the windowpane flounder was primarily a predator upon epibenthic invertebrates, with a preference for the shrimps *Neomysis americana* and *Crangon septemspinosa*. As neither of these organisms was captured in substantial quantities during the coincident benthic survey, this flounder appeared to be a rather selective feeder. The inclusion of fish in its diet also revealed its ability to capture swift-moving prey, probably both near the bottom and in the water column. As the incidence of many of the food items in the stomachs examined was correlated with their seasonal abundance and availability, it also appeared to be opportunistic. Feeding was active during the daylight hours, when the collections were made, as evidenced by the few empty stomach (5 of 120) and the minute amount of digested matter therein. As no plant material was eaten, the flounders were strictly carne-

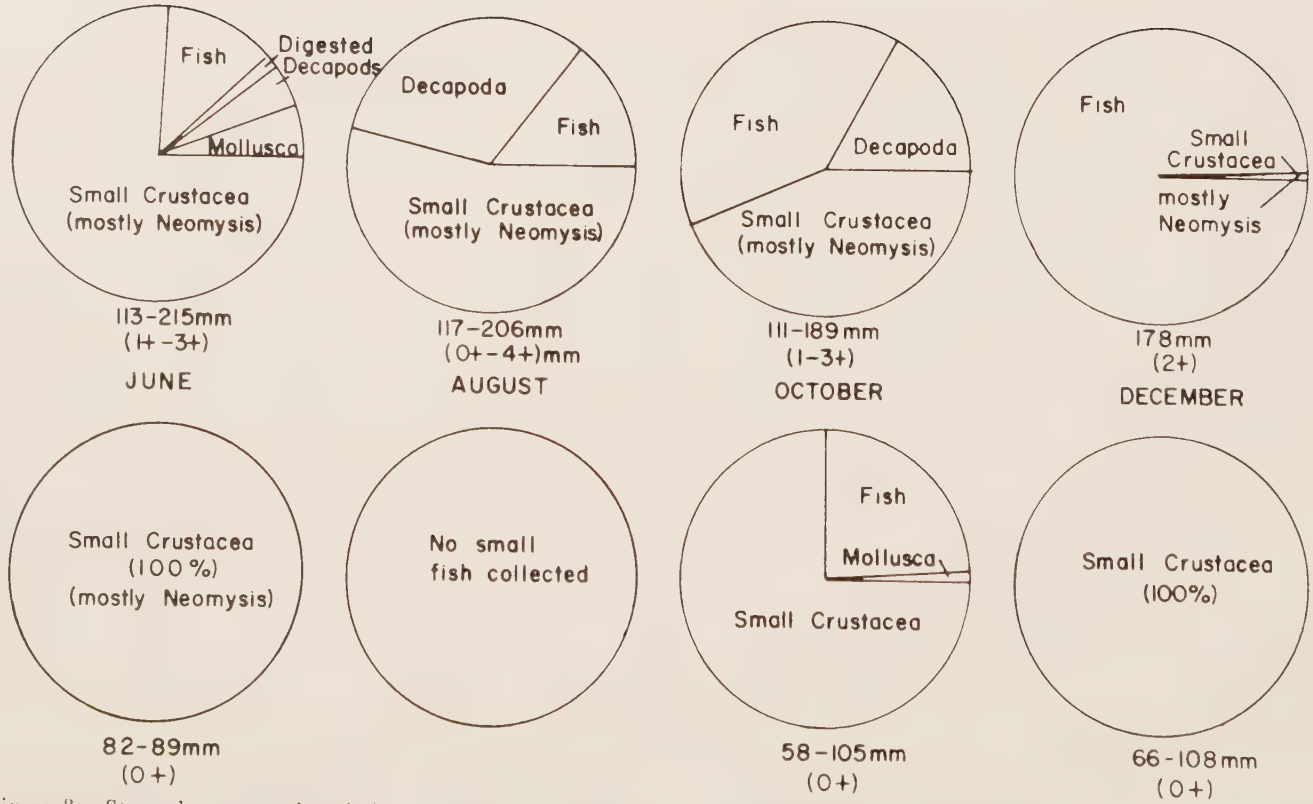

Figure 3. Stomach contents in relation to fish size for windowpane flounders taken by trawling offshore at Northport (N.Y.) during different months. Diagrams represent percentage by volume.

vores which fed on the third trophic level. These data indicate that the species is capable of feeding on a variety of organism types and is able to adapt to the seasonal availability of food items in its environment.

It is evident that stomach content analyses can provide valuable information on the behavior of fish species. When feasible during aquatic ecological studies (freshwater or marine), such analyses may be employed to increase or enhance the available data on the ecology of indigenous fishes as well as on the presence and seasonal abundance of their prey organisms. Dietary studies of fishes should incorporate a coincident program of benthic sampling to provide supplemental data not only on invertebrates but also on plants (both microscopic and macroscopic) and demersal fish eggs and larvae. Stomach content analyses of many fish species from the same area contribute to an over-all understanding of predation and feeding pressure and thus the level of competition between species. It is, therefore, desirable to study more than one or a few species concurrently. Coincident studies of physical parameters such as temperature, salinity, pH, dissolved oxygen, tides, currents, sediments, etc. permit accurate explanations of seasonal, temporal and spatial variations in both predators and prey.

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GENERAL NOTES

USE OF ROMANOWSKY STAINS TO PREPARE TOOTH SECTIONS FOR AGING MAMMALS[1]

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In recent years, counting the cementum annuli of teeth has become an accepted technique for aging a number of mammalian species. This technique has proven more accurate than subjective methods such as tooth wear and is being used increasingly by wildlife biologists in population dynamics research. At the Wildlife Research Laboratory at Delmar (N.Y.), tooth sections from the red fox (*Vulpes fulva*), gray fox (*Urocyon cinereoargenteus*), black bear (*Ursus americanus*) and white-tailed deer (*Odocoileus virginianus*) have routinely been stained with hematoxylin or hematoxylin and eosin (Sauer et al., 1966; Monson et al., 1973). However, an improved staining technique that would more clearly define the cementum annuli was desirable for increased accuracy and speed of reading such sections. Working with the sea otter (*Enhydra lutris*), Schneider (1973) compared tooth sections stained with Harris' hematoxylin, Paragon multiple stain and Giemsa stain. Giemsa-stained sections were judged superior. Because of Schneider's findings, Giemsa stain and others of the Romanowsky family, such as Field stain and Wright stain, were tested. These stains are widely used for staining blood cells and blood parasites (Russell et al., 1963), but not for staining tooth sections.

Incisors from white-tailed deer and premolars from other species were used. All teeth were decalcified in a 20 per cent formic acid solution until soft, usually from 24 to 48 hours. Following decalcification, the teeth were placed in distilled water for 24 hours. They were sectioned at an approximately 12-micron thickness with a freezing microtome. The sections were placed on slides and dried on a slide warmer prior to staining.

Tooth sections from 150 red foxes, 82 gray foxes, 12 wild canids (*Canis latrans* var.), 363 black bears, 31 fishers (*Martes pennanti*), 2 martens (*Martes americana*), 3 raccoons (*Procyon lotor*), 1 bobcat (*Lynx rufus*) and 240 white-tailed deer were stained with Giemsa stain. Those from deer were placed in a solution of one part Giemsa stain to 10 parts distilled water for 25 minutes, while those from the other species were stained in a solution of one part Giemsa stain to 25 parts distilled water for 20 minutes. After staining, the slides were rinsed in two changes of tap water and one of distilled water. The slides were then dried, and the sections were mounted either in diaphane or dried, cleared for 15 minutes in xylene and mounted in a namount or coverbond.

Tooth sections from eight red foxes, four gray foxes, six black bears and four white-tailed deer were stained with Maximow stain. They were first stained in Maximow A solution for 15 minutes, rinsed in water (45° C.) for 2 minutes and then stained in Maximow B solution for 30 minutes. The slides were then washed in water, blotted and immersed in absolute ethyl alcohol for approximately 1 minute or until the sections turned blue. The mounting procedure was the same as for Giemsa stain.

Tooth sections from 36 red foxes, 34 gray foxes, 85 black bears, 14 fishers, 4 raccoons and 24 white-tailed deer were stained with Field stain. Slides with attached, dry tooth sections were immersed in Field stain 1 for approximately 10 seconds and rinsed in tap water until no more stain ran off. They were then stained with Field stain 2 for 20 seconds, rinsed in tap water and mounted as described for Giemsa stain.

[1] A contribution of Federal Aid in Fish and Wildlife Restoration Project W-35-R.

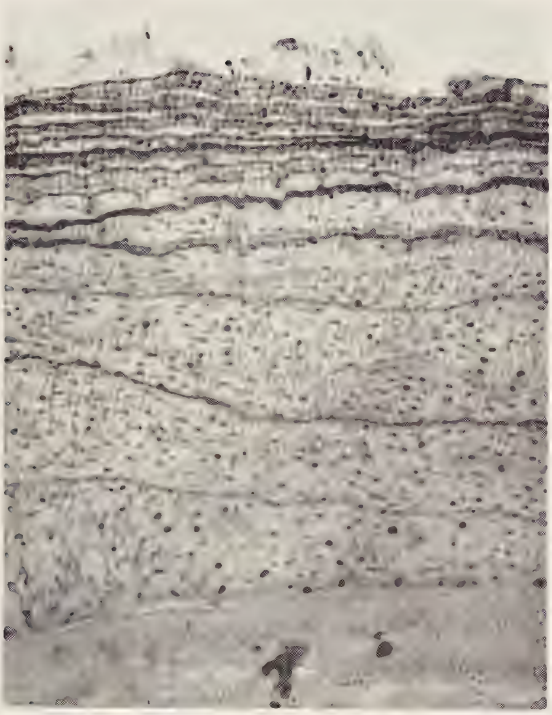

Figure 1. A Giemsa-stained section of a premolar from an approximately 12½-year-old black bear. (×200)

Figure 2. A Field-stained section from a 3½-year-old raccoon. (×200)

Tooth sections from four red foxes, six gray foxes, three black bears and three white-tailed deer were stained with Wright stain. Slides with attached, dry tooth sections were flooded with the stain for from 2 to 20 minutes. Then water was added, and the stain and water mixture was blown upon until a metallic sheen formed on the surface. After 2 minutes the diluted stain was washed off with a jet of tap water, and the sections were dried and mounted as described for Giemsa stain.

The Giemsa, Maximow and Field solutions consistently produced well stained sections in which the cementum annuli were easily distinguished under a microscope. Sections treated with Wright stain were poor and difficult to read. Tooth sections stained with either Giemsa or Maximow stain were generally slightly better than those stained with Field stain. However, Field stain has the advantage of permitting sections to be processed more rapidly. Figures 1 and 2 illustrate tooth sections stained with Giemsa and Field stains, respectively.

Tooth sections stained with Giemsa, Maximow or Field stain were of markedly betted quality for determining age than the hematoxylin and eosin techniques previously used. Also, these stains are inexpensive and the procedures simple.

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A BLACK BEAR SUFFERING FROM PARALYSIS OF THE HINDQUARTERS[1]

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A black bear (*Ursus americanus*) was shot in the Town of Keene in Essex County (N.Y.) which, because of its emaciated condition and injuries to the hindquarters, was submitted to the Wildlife Research Laboratory at Delmar for

Figure 1. Anterior aspect of bear's hind legs showing abraded areas on knees and top of paws.

[1]A contribution of the Federal Aid in Fish and Wildlife Restoration Project W-35-R. The authors wish to thank personnel of Project W-89-R for aging the bear and Nick Drahos for the photographs.

Figure 2. The bear's lumbar vertebrae, sectioned agittally, showing displaced spinal chord.

examination. The bear was a 12- to 14-year-old female but had a dressed weight of only 68 pounds. Lacerations and abrasions were noted on the anterior aspect of both hind feet at the level of the metatarsal-phalangeal joints and on both knees (Figure 1). The muscles of the hind legs were atrophied, while those of the front legs were normal. A longitudinal section of the lumbar vertebrae revealed a well ossified fracture (Figure 2) with spinal cord damage. X-rays of the fractured vertebrae failed to reveal any lead fragments. Although the bear had been field dressed, the ovaries were intact. Ovarian scars indicated that she had ovulated.

Because of the well ossified fracture of the lumbar vertebrae, it seems likely that this injury had been sustained in mid- or late summer, probably as the result of a fall or from being hit by a motor vehicle. The damaged spinal cord resulted in paralysis of the hindquarter muscles which became atrophied from disuse. The lesions on the hind legs and feet were caused by wear as the bear dragged her hindquarters over the ground.

This case is witness to the tremendous fortitude exhibited by many wild animals. The shooting of this bear was an act of mercy which spared the animal the fate of gradual starvation.

ANOMALOUS-FURRED MUSKRATS[1]

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Two male muskrats (*Ondatra zibethicus*), trapped within three-quarters of a mile of one another on different streams in Cayuga County (N.Y.), one in De-

Figure 1. One of the anomalous-furred muskrats (right) compared with a normally furred specimen (left).

[1]A contribution of the Federal Aid in Fish and Wildlife Restoration Project W-35-R and the New York State Rabies Control Project. The authors wish to credit the photograph (Figure 1) to John Goerg.

cember 1973 and the other in January 1974, were submitted to the Wildlife Research Laboratory at Delmar for examination. Because of the thin and unusual appearance of their pelts, the trapper feared a disease condition that might seriously affect the local muskrat population.

Gross examination revealed thinner underfur than normal and a conspicuous sparsity of guard hairs (Figure 1). The few guard hairs present were thin, wavy and pale in the proximal and medial regions; however, the length of these hairs (3.0 to 3.5 centimeters) were comparable to those for a normal muskrat. The skin of the ventral abdominal, thoracic and axillary regions appeared hyperemic, possibly due to thermoregulatory imbalances or trauma induced by the trapping. Little subcutaneous or mesenteric fat was present, but no gross abnormalities of the internal organs were noted. However, in view of the appearance of the hides, a thallium assay was performed on liver samples and proved negative. A few hypha-like elements were noted on the surface of the epidermis in H and E stained sections of the skin. No inflammatory reactions or abnormalities were observed in or about the hair follicles. Cultures done by the Mycology Laboratory of the New York State Department of Health did not reveal any fungal pathogens.

The anomalies of these muskrat hairs differed from the woolly-coated anomaly of white-tailed deer (*Odocoileus virginianus*) reported by Friend and Hesselton (1966) in that the cuticular scale pattern was normal. The cuticular scale patterns of the guard hairs and underfur were consistent with those reported and illustrated for normal muskrats by Adorjan and Kolenosky (1969). Microscopic examination of the guard hairs and underfur revealed a medullary core which was discontinuous, fragmented and deficient in cornified cells and air cells (Figures

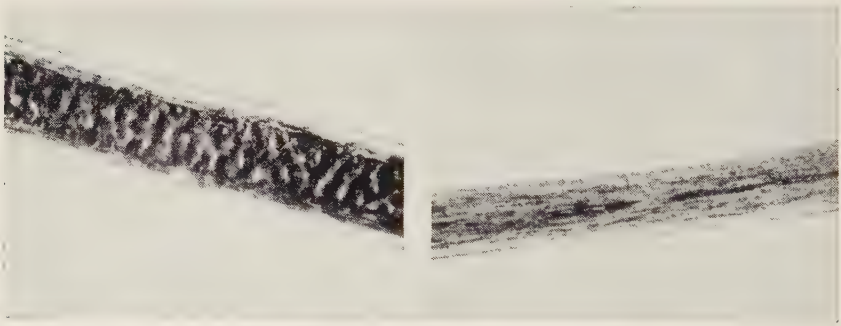

Figure 2. Guard hair from anomalous-furred muskrat (right) showing thinness and discontinuous and fragmented medulla in the medial region of the shaft compared with a normal guard hair (left). (×250)

Figure 3. Underfur hair from an anomalous-furred muskrat (right) showing thinness and discontinuous and fragmented medulla in the medial region of the shaft compared with a normal underfur hair (left). (×250)

2 and 3). Pigment granules formed elliptical pockets between the lamellae of the cortex, occasionally resulting in bulges of the overlying cuticle of the guard hairs. The difference in mean medial width between 10 normal and 10 anomalous guard hairs was 68 microns, and that between similar groups of underfur hairs was 6.7 microns. These measurements corresponded well with the medullary widths of normal guard hairs and underfur. Therefore, the thinness and waviness of the abnormal muskrat hairs were the respective results of medullary deficiencies and discontinuities.

Because of the identity and nature of the clinical appearance of the two muskrats, the close proximity of the sites where they were taken and the occurence of normal muskrats in the same area, it seems reasonable to conclude that the anomalous hair condition was congenital. It is interesting that these poorly furred muskrats were able to survive in the cold water and weather of central New York in December and January. This is believed to be the first report of this condition in muskrats.

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NOTES ON LUMPFISH FROM MONTAUK, NEW YORK[1]

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Lumpfish or lumpsuckers (*Cyclopterus lumpus*) are reported to occur on both sides of the North Atlantic Ocean. On the eastern coast of North America, they are common in the waters of Canada and northern New England, and they are found southward to New Jersey and Chesapeake Bay rarely (Bigelow and Schroeder, 1953; Leim and Scott, 1966). They are known to occur in New York waters (Nichols, 1913; Gordon, 1951), but the only occurrences reported from Long Island were six fish by Latham (1919) and two by Bigelow and Schroeder (1953), all from Orient. Gordon (1951) stated that the status of lumpfish in the waters of Block Island Sound, Peconic Bay and Gardiner's Bay was unknown. Although this species is occasionally captured by commercial fishermen from these areas in the spring, its occurrence there has not been reported in the literature.

Two lumpfish were captured in a commercial pound (trap) net in a rocky area of Fort Pond Bay at Montauk during April of 1974. Fort Pond Bay is situated south of Block Island Sound and southeastward across Gardiner's Bay from Orient. Thus, these specimens are the first recorded from this part of these waters.

The first fish, captured on April 27 (water temperature about 9.2° C.) was a ripe male which measured 240 millimeters in standard length, 295 millimeters (11.6 inches) in total length and weighed 1,055 grams (2.32 pounds). The gonads weighed 21.8 grams and accounted for 2.07 per cent of the body weight. A firm squeeze of the abdomen caused the release of milt. The color of this male was charcoal mottled with dark red dorsally and laterally. Ventrally, the area surrounding the suctorial disc was a vivid red. The internal lining of the body cavity and the ventral musculature were both bright pink in color. The stomach was empty.

The second fish, captured on April 30 (water temperature 10.1° C.), was a ripe female which measured 340 millimeters in standard length, 393 millimeters (15.5 inches) in total length and weighed 2,725 grams (6.0 pounds). The gonads weighed 606 grams and accounted for 22.24 per cent of the body weight. A firm squeeze caused the release of translucent pink ova numbering about 125,000. Bigelow and Schroeder (1953) stated that 18-inch females may produce up to 136,000 eggs, while Gordon (1960) recorded a 21-pound, 23.5-inch specimen containing 279,620 eggs. The ova of the present specimen measured 2.18 to 2.20 millimeters in diameter and contained well over 50 oil drops ranging in size from 0.025 to 0.400 millimeter. Preservation for 3 weeks in 25 per cent formalin reduced the diameter of the ova to about 1.90 millimeters and altered their color to a translucent yellowish-white. Hildebrand and Schroeder (1972) reported egg diameters of 2.2 to 2.6 millimeters, a size range greater than that for the present specimen presumably as a result of fertilization. The color of this female was charcoal dorsally and laterally and light gray ventrally. The internal lining of the body cavity was bright silvery white and the ventral musculature was white. The stomach was empty.

Leim and Scott (1966) stated that lumpfish 4 inches long are in their third year and that when they reach 10 inches they are in their fifth year. Bigelow and Schroeder (1953) stated that maturity is probably attained in the third year. The two fish reported here, then, were probably 5 years or more of age.

Lumpfish are reported to be the host for two species of copepod parasites, *Sphyrion lumpi* (Mann, 1970) and *Lernaeocera branchialis* (Sindermann, 1970). The latter copepod is primarily parasitic on gadid fishes, with lumpfish as the intermediate host. Examination of the two lumpfish caught, however, revealed neither to be present.

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[1]Contribution No. 29 of the New York Ocean Science Laboratory. The authors wish to acknowledge the advice of Dr. Herbert M. Austin, the photography of Carl O. Mamay and the help of Richard A. Amish, Stephan K. Gill, Adelard Lessard and Alfred H. Wiedow.

Ripe female (top) and ripe male (bottom) lumpfish (*Cyclopterus lumpus*) caught in Fort Pond Bay at Montauk (N.Y.) in April 1974.

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A DESCRIPTIVE INDEX OF HABITAT SHAPE IRREGULARITY[1]

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It is widely recognized that, all other factors being equal, the more border (between vegetative cover types, or between land and water) per component unit, the more valuable an area is likely to have as wildlife habitat. A numerical, objective index of this relationship would be useful in a variety of ways. For instance, the amount of border between cover types, or between marsh and upland, might be one among a set of criteria for establishing priorities for wildlife habitat acquisition. An index that permitted objective comparison among areas would be of significant utility.

A measure that comes to mind immediately is border length per unit area. This has the advantage of being numerical and objective, but it also has certain disadvantages. First, such a measure has little graphic meaning because there is no physical standard for comparison. Second, such a measure is heavily weighted to give a high index for small units since the perimeter decreases at a rate that is only the square root of the decrease in area. This effect becomes especially important when the unit involved is so small as to be meaningless as habitat for most birds and mammals. A measure of shape irregularity that is independent of size (size can be dealt with separately) would be more useful than border length per unit of area.

[1]A contribution of Federal Aid in Fish and Wildlife Restoration Project W-129-R. The author wishes to acknowledge the participation of Stephen Browne, associate wildlife biologist, in developing the idea.

The method described here derives from the fact that a circle has the smallest possible perimeter for the area enclosed, and that, as the area changes, the change in the perimeter/area ratio is the same for a circle as for any other figure. The circle would, therefore, serve well as a unit by which to index shape irregularity. The method evolved from a study of the graphs in Millar (1969) in which wetland shoreline per unit area is plotted against the total area and the theoretical curve of the same for circles is also shown. The method, simply, is to divide the perimeter of a unit, as measured, by the circumference of a circle having an equal area. The equation for this "shape irregularity index" can be simplified to:

$$\text{S.I.} = \frac{0.28P}{\sqrt{A}}$$

where S.I. = shape irregularity index
P = perimeter of unit as measured
A = area of unit

The index is derived as follows:

$$\text{S.I.} = \frac{P}{C}$$

where C = circumference of a circle having an area equal to A,
or $C = 2\sqrt{\pi A}$

Therefore:

$$\text{S.I.} = \frac{P}{2\sqrt{\pi A}}$$

$$= \frac{P}{3.54\sqrt{A}}$$

$$= \frac{0.28P}{\sqrt{A}}$$

This index has a number of good qualities. It is graphic, since any unit area is evaluated in comparison with the visualizable form of a circle. It is constant for any given shape regardless of size. In machine coding for data retrieval in wildlife habitat work, two or three digits are all that is necessary to give a meaningful index of shape irregularity.

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Errata

In the January 1975 issue (Vol. 22, No. 1) the maps shown on pages 1 and 52 should be reversed, but not the captions.

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